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ON THE EXPERIMENTS WITH THE PERKINS MACHINERY OF THE STEAM YACHT "ANTHRACITE."

By Chief-Engineer ISHERWOOD, United States Navy.

The *Anthracite* is the British steam yacht, 86 feet 4 inches long between perpendiculars, 16 feet 1 inch greatest breadth of beam, 10 feet 2 inches depth of hold, and 9 feet mean draught of water, that made a brief visit to the United States during the last summer for the purpose of exhibiting her machinery, which is constructed according to the system of Mr. Loftus Perkins, and embraces some novelties of mechanical detail, as well as the use of steam of higher pressure with greater expansion than has ever before been employed. The engine drives a 2-bladed screw of 6 feet 1 inch diameter and 9 feet pitch, and is peculiar in the compounding of its cylinders. The arrangement of the tubes of its surface condenser is also peculiar, and the design of the boiler is likewise new.

The superior economy of fuel claimed for this system is inferred from the exceedingly high steam pressure employed and the very great measure of expansion with which it is used, both being largely in excess of any previous practice. And, with the view of giving the fullest effect to the expansion, provision is made in the boiler for highly superheating the steam. In other words, the system of Mr. Perkins

is an attempt to realize practically the gain in economy inferable theoretically from the use of steam of higher pressure than heretofore employed and with a measure of expansion correspondingly greater. On these two hang all the law and the prophets of this system. There is nothing new in either, the system of Mr. Perkins being merely an extension of what has been in progress for many years. It embodies no new principles, but only endeavors to give those previously employed a more extended application by means of mechanical details better adapted for that purpose.

The steam is generated from water distilled from fresh water; and the wastage, inevitable in any case, is supplemented with water distilled from fresh water carried for that contingency, water distilled from sea water not being considered sufficiently pure for use with this system of machinery. The distillation is effected in a separate vessel. No lubricants are used in the valve chests and cylinders, but a bronze of peculiar composition and manipulation in manufacture is relied on without lubrication for the material of the rubbing surfaces of the steam valves and pistons, and, as the cylinders are vertical, the water lubrication, which in the engine of the *Anthracite* was excessive, in conjunction with this bronze appears to be sufficient to prevent abrasion. Experience with horizontal cylinders, or with those having but a slight water lubrication, might not be so satisfactory. The manufacture of this bronze is a trade secret.

Whether any gain in economy over the best existing practice can be obtained by employing steam of higher pressure with greater expansion is a question to be answered by experiment only, like any other question in physics. It cannot be answered inferentially from an abstract consideration of the properties of steam of high and low pressures, or from the gain due to the laws of expanding gases. The question must be directed to Nature, who alone is competent to give a correct reply, and it must be put in the language of experiment under the precise conditions in which the steam is to be used, so that the modifications effected by the material of the mechanism and by its mode of action may be included in the final result.

Only two experiments have been made with the machinery of the *Anthracite* to the knowledge of the writer; one in England on the 22d of May, 1880, by Mr. F. J. Bramwell, an expert employed for that purpose by the Directors of the Perkins Engine Company, whose report to them was reprinted in the September number of this journal

for 1880; the other was made by order of the Navy Department on the 13th and 14th of August, 1880, by a Board of Chief Engineers of the United States Navy, presided over by Chief Engineer Loring.

The results of the two are widely discordant. From the very able and complete report of Chief Engineer Loring to the Bureau of Steam Engineering of the Navy Department I have taken freely all the facts and calculations reproduced in this paper; and in a succeeding one I shall give the corresponding data and results of Mr. Bramwell's experiment, similarly arranged, the facts of which cannot be found in his report as printed in this journal, but which the writer has obtained from authentic drawings of the machinery and from the indicator diagrams given in a supplement to that report to the Directors and reproduced in their lithographic copy for distribution.

Before giving the data and results of the experiments it is necessary to preface them with a description of the machinery with which and the manner in which they were made.

Engine.

There is one engine of the vertical, direct-acting, inverted type, with three compounded cylinders of different diameters but same stroke of piston, the first two being single acting and the third double acting. The first or smallest cylinder is placed immediately above the second or next largest with their axes is the same vertical line. The third or largest cylinder has its axis parallel to the axes of the first and second cylinders, and is situated forward of them relatively to the vessel. The axes of all the cylinders are in the vertical plane passing lengthwise through the centre of the vessel. The casting of the first cylinder forms also the top cover of the second cylinder, the bottom of the first being open to or in common with the top of the second. The pistons of these two cylinders are connected by a casting of nearly the diameter of the first cylinder, and the space between the pistons is in common with the receiver. The first cylinder receives into its top the steam direct from the boiler, and its piston makes a downward stroke, at the end of which the steam is exhausted through a connecting pipe of 6·4918 square inches cross area and 29 inches length direct into the bottom of the second cylinder, whose piston makes the return upward stroke. From the second cylinder the steam is exhausted into a receiver from which the third cylinder is supplied alternately at top and bottom; this last cylinder exhausts into a surface condenser. The

engine thus, in effect, acts like an ordinary compound engine of two cylinders with an intermediate receiver.

The peculiar arrangement or combination of the first and second cylinders is for the same purpose as the compounding of the two cylinders of an ordinary compound engine, namely, to lessen the initial pressure on the crank pin, and to reduce the cylinder condensation by making the sum of the products of the difference of the temperatures due to the extreme pressures in the cylinders by the inner surfaces of the cylinders, less than in the case of a single equivalent cylinder giving the same mean pressure with the same boiler and final back pressure and the same measure of expansion. It is merely a further extension of the principle of the compound engine, being the same thing, only more so.

The first cylinder has at its top two double beat valves of the Cornish type, one for admitting the steam and cutting it off when a portion of the stroke of the cylinder is completed; the other for exhausting it at the end of the stroke into the second cylinder. This exhaust valve of the first cylinder is thus the steam valve of the second cylinder. The second cylinder has only one similar double beat valve and it exhausts the steam from the second cylinder into the receiver. The third cylinder has an ordinary three-ported slide valve with an expansion slide upon its back, the latter being worked from a prolongation upwards of the circulating pump rod. The valves of the first and second cylinders are worked by two eccentrics and a Stephenson link placed at one end of the crank shaft. The valve of the third cylinder is similarly worked by two eccentrics and a Stephenson link placed at the other end of the crank shaft. The reversal of the movement of the engine is effected by these links.

The Cornish valves are directly moved by lifting rods which rise and fall vertically, and whose upper end fit loosely into close-topped sockets made in the valves themselves, so that after the latter are seated the rods can recede from them. Cams working in yokes made in the lifting rods control the adjustment of these valves, whose upper faces are divided into two sections.

The cylinders and their covers are steam-jacketed in a peculiar manner. Coils of wrought iron pipe being properly placed in the mould, the metal of the cylinders and covers was cast around them and they thus became imbedded in its centre. The water of condensation in

the jackets was delivered into the condenser. The exterior of the cylinders and their covers was efficiently lagged.

From the bottom of the piston of the second cylinder there proceeds a piston rod whose lower end is secured into a crosshead moving between guides. From the cross-head journal the connecting rod continues directly to the crank pin. From the bottom of the piston of the third cylinder there proceeds a piston rod whose lower end is secured into a cross-head moving between guides, and from the journal of this cross-head a connecting rod proceeds directly to the crank pin. The crank shaft has two crank pin journals and four main journals.

The areas of the pistons of the three cylinders, exclusive of their rods, have the following proportions: Calling the area of the piston of the first cylinder 1·00000, the area of the piston of the second cylinder is 4·26212, and that of the third cylinder is 17·20179 including both sides of the piston as the third cylinder is double acting while the first and second cylinders are single acting.

In the first cylinder the steam is used for about the first half of the stroke of its piston without expansion, and during the remaining half expansively. In the second and third cylinders the steam is wholly used expansively, the cut off valve of the third cylinder acting only as a throttle valve to increase the back pressure against the piston of the second cylinder.

The circulating pump supplying the refrigerating water to the condenser is worked by a lever articulated to the piston rod of the third cylinder, and the air pump is worked by a similar lever similarly articulated to the piston rod of the second cylinder. The feed pumps and bilge pumps are worked by the cross-heads of the circulating pump and of the air pump. All the pumps are vertical and single acting.

The surface condenser is composed of galvanized wrought iron tubes, one-half of which have an inner diameter less than the outer diameter of the remaining half, so that those of the smaller diameter can be placed within those of the larger diameter and leave an annular space between when the axes of both coincided. All the tubes stand vertically and are arranged in pairs, a smaller and a larger diameter tube constituting a pair, with the smaller placed concentrically inside of the larger. Thus one-half of the tubes having the same diameter are outer tubes and the remaining half having the same diameter are inner tubes. The outer tubes have their upper end closed and their

lower end open and screwed into their horizontal tube plate. The inner tubes have both ends open and are screwed by their lower end into their horizontal tube plate, which is directly beneath the first tube plate. The upper open end of the inner tubes is within a very short distance of the upper closed end of the outer tubes. The refrigerating or injection water is forced by the circulating pump up the inner tubes and thence into the annular space between the inner and outer tubes down which it descends and passes overboard.

All the tubes are surrounded by the condenser shell, which forms, with the two tube plates, three compartments—one above the upper tube plate, one between the tube plates, and one beneath the lower tube plate. The upper compartment receives the exhaust steam from the third cylinder, which steam surrounding the outer tubes is condensed on their exterior surfaces, the water of condensation trickling down to the upper tube plate; this compartment communicates with the air pump which drains it. The lower compartment receives the refrigerating water from the circulating pump and distributes it to the inner tubes. The intermediate compartment, or the one between the tube plates, receives the refrigerating water from the annular spaces between the tubes of each pair, and passes it to the outboard delivery valve.

This arrangement of the tubes is exceedingly compact, makes perfectly tight joints with the tube plates, and allows free and independent expansion to each tube, but it has serious disadvantages as compared with the ordinary arrangement. It is greatly less accessible for examining, removing and replacing the tubes, few or many; in fact, these operations require the condenser to be taken apart; for, although the top of the shell is removable after the manner of a cover, yet, practically, the long flexible tubes, once firmly screwed into their plates and rusted there, could not be unscrewed by their upper ends, as intended by the designer. The power required to work the circulating pump is very much greater on account of the sharp reversal of the refrigerating water at the upper ends of the tubes, and on account of the resistance of the greater quantity of tube surface over which the water must be passed. The quantity of tube surface is nearly double, the surface of all the inner tubes being in excess of the surface required with the ordinary arrangement. This, also, in the same proportion, increases the weight of the condenser and the cost of its manufacture. The sole use of the inner tubes is to convey the refrigerating water to

the upper end of the outer tubes, only the exterior surface of which constitute the condensing surface; hence, all the inner tubes are in addition to what would be required with the ordinary arrangement to give equal condensing surface. The designer was doubtless led to the adoption of his arrangement of tubes by the perfection of the joint it afforded; for, with his system, any leakage of refrigerating water (which would be sea water) into the compartment receiving the water of condensation was inadmissible, as that much sea water would have passed into his boiler, but he paid dearly for this advantage.

The following are the principal dimensions and proportions of the engine:

Number of cylinders,	3.
Diameter of the 1st cylinder (single acting),	$7\frac{3}{4}$ inches.
Stroke of the piston of the 1st cylinder,	15 inches.
Area of the piston of the 1st cylinder,	47·173 sq. inches.
Space displacement of the piston of the 1st cylinder, per stroke,	0·4094884 cu. ft.
Space in clearance and steam passage of 1st cylinder,	0·0856481 cu. ft.
Diameter of the 2d cylinder (single acting),	$15\frac{3}{16}$ inches.
Diameter of the piston rod of the 2d cylinder,	$2\frac{3}{4}$ inches.
Stroke of the piston of the 2d cylinder,	15 inches.
Net area of the piston of the 2d cylinder,	190·389 sq. inches.
Space displacement of the piston of the 2d cylinder, per stroke,	1·6526823 cu. ft.
Space in clearance and steam passage of 2d cylinder,	0·3116325 cu. ft.
Diameter of the 3d cylinder (double acting),	$22\frac{3}{16}$ inches.
Diameter of the piston rod of the 3d cylinder,	$2\frac{3}{4}$ inches.
Area of upper side of piston of 3d cylinder	408·700 sq. inches.
Net area of lower side of piston of 3d cylinder,	402·760 sq. inches.
Mean area of the two sides of the piston of 3d cylinder,	405·730 sq. inches.
Stroke of the piston of the 3d cylinder,	15 inches.
Mean space displacement of the piston of the 3d cylinder, per stroke,	3·5219618 cu. ft.
Space in clearance and steam passage of 3d cylinder at one end,	0·3194444 cu. ft.

Area of steam port of 1st cylinder ($1\frac{1}{4}$ by $2\frac{1}{2}$ inches =)	$3\frac{1}{8}$ square inches.
Area of exhaust port of 1st cylinder ($1\frac{1}{4}$ by 4 inches =)	5 square inches.
Area of exhaust port of 2d cylinder ($1\frac{1}{2}$ by $13\frac{1}{2}$ inches =)	$20\frac{1}{4}$ square inches.
Area of steam port of 3d cylinder (2 by $16\frac{3}{4}$ inches =)	$33\frac{1}{2}$ square inches.
Area of exhaust port of 3d cylinder (4 by $16\frac{3}{4}$ inches =)	67 square inches.
Depth of piston of 1st cylinder occupied by the packing rings, . . .	$3\frac{1}{2}$ inches.
Depth of piston of 2d cylinder occupied by the packing rings, . . .	$3\frac{1}{2}$ inches.
Depth of piston of 3d cylinder occupied by the packing rings, . . .	$4\frac{1}{8}$ inches.
Total depth of piston of 2d cylinder, .	5 inches.
Total depth of piston of 3d cylinder, .	$5\frac{5}{8}$ inches.
Thickness of metal of all the three cylinders,	$1\frac{1}{2}$ inches.
Total interior surface of the 1st cylinder exposed to the contact of the steam, including the upper surface of the piston and the surfaces of the steam passages and clearance, . .	5·09236 sq. feet.
Total interior surface of the 2d cylinder exposed to the contact of the steam, including the lower surface of the piston, half the surface of the piston rod, and the surfaces of the steam passage and clearance, . . .	13·06982 sq. feet.
Total interior surface of the 3d cylinder exposed to the contact of the steam, including both surfaces of the piston, half the surface of the piston rod, and the surfaces of all the steam passages and clearances, . . .	22·52750 sq. feet.
Outside diameter of the wrought iron pipe composing the coils of the steam jackets for the three cylinders, . . .	$\frac{5}{8}$ inch.
Inside diameter of the wrought iron pipe composing the coils of the steam jackets for the three cylinders, . . .	$\frac{3}{8}$ inch.

Distance between the axes of the coils of the wrought iron pipe composing the steam jackets for the three cylinders, . . .	$1\frac{1}{16}$ inches.
Per centum of the interior surface of the cylinders steam jacketed, being the ratio of the inside surface of the wrought iron pipe composing the coils of the jackets to the interior surface of the cylinders. These coils are in both top and bottom of the cylinders as well as around the sides, . . .	60·80
Clearance of all the cylinders, . .	$\frac{3}{8}$ inch.
Inner diameter of the steam pipe from boiler, .	$1\frac{1}{8}$ inches.
Cross area of the steam pipe from boiler, .	0·994 sq. inch.
Ratio of cross area of steam pipe to area of piston of 1st cylinder, . . .	0·02107
Cross area of pipe connecting top of 1st cylinder with bottom of 2d cylinder, . .	6·4918 sq. inches.
Length of pipe connecting top of 1st cylinder with bottom of 2d cylinder . .	29 inches.
Ratio of the space displacement of the piston of the 1st cylinder in equal time to that of the piston of the 2d cylinder, . .	4·03597
Ratio of the space displacement of the piston of the 1st cylinder in equal time to that of the piston of the 3d cylinder, . .	17·20179
Ratio of the space displacement of the piston of the 2d cylinder in equal time to that of the piston of the 3d cylinder, . .	4·26212
Ratio of the aggregate displacements of the pistons of the 1st and 2d cylinders in equal time to that of the piston of the 3d cylinder, .	3·41578
Ratio of the space in clearance and steam passage of 1st cylinder to the space displacement per stroke of its piston, . . .	0·209159
Ratio of the space in clearance and steam passage of 2d cylinder to the space displacement per stroke of its piston, . . .	0·188561
Ratio of the space in clearance and steam passage of 3d cylinder to the space displacement per stroke of its piston, . . .	0·090707

Diameter of crank shaft,	5½ inches.
Condensing surface in condenser,	422 square feet.
Diameter of air pump (one, vertical and single acting),	11½ inches.
Stroke of air pump piston,	4½ inches.
Diameter of circulating pump (one, vertical and single acting),	11½ inches.
Stroke of piston of circulating pump,	4½ inches.
Diameter of feed pumps (two, single acting),	2 inches.
Stroke of feed pumps' pistons,	4½ inches.
Diameter of bilge pumps (two, single acting),	3 inches.
Stroke of bilge pumps' pistons,	4½ inches.
Length in vessel occupied by engine and boiler,	22½ feet.
Total weight of machinery, including engine, boiler, screw shaft, screw and all appurtenances except water in boiler,	25 tons.
The tank in the engine room, carrying distilled water for supplying the boiler wastage, contains	280 pounds.

It will be observed from the above dimensions that the spaces in the clearances and steam passages of the cylinders are enormous, as compared with what are usually found in good practice, being from twice to four times greater than necessary, and involving a proportionally decreased economic effect from the steam. Although the Cornish equilibrium valves may be indispensable for working with steam of the high pressure intended in the first and second cylinders, yet they may be arranged so that the spaces in the clearances and steam passages shall not exceed 5 to 6 per centum of the space displacement of the respective pistons per stroke. And, certainly, the ordinary slide valve can be adapted to the third cylinder without requiring over 9 per centum of the space displacement of its piston per stroke in waste spaces.

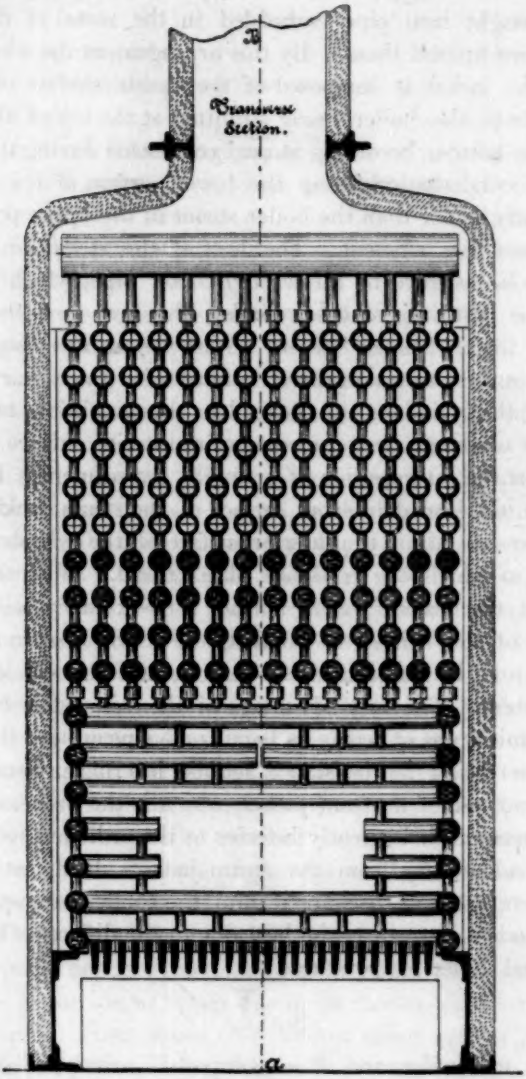
The disadvantage of the unusually large waste spaces at the ends of the cylinders is not limited to the loss of steam required to fill them, but extends to the loss of steam due to its condensation on the surfaces of these spaces. These losses of economic effect, greater in the engine of the *Anthracite* than is found in ordinary engines, are not inherent to the Perkins system, and may easily be eliminated by a better design of mechanical details.

The method of steam jacketing the cylinders is very inefficient, so much so, indeed, that probably but little economic effect is obtained from their use. The jackets, as already described, are composed of coils of wrought iron pipe embedded in the metal of the cylinder which was cast around them. By this arrangement the whole heating surface of the jacket is composed of the inside surface of the pipe. The steam from the boiler, being admitted at the top of the coil, follows it to the bottom, becoming in part condensed during the progress, the water of condensation filling the lower portion of the coil, which is consequently cooler than the boiler steam in the upper portion, and, to that extent, less efficient. The heat of the steam or of the hot water has to be accepted by the wrought iron pipe, which then delivers it to the cast iron of the cylinder, the heat wave being much impeded by this additional barrier. With the ordinary steam jacket, the boiler steam is at once in direct contact with every particle of the cast iron of the cylinder; the jacket has the maximum temperature, and the heat is communicated to the entire interior surface of the cylinder without the interposition of a single impediment. In the Perkins system, the heat-delivering surface of the steam jacket or coil is only 60·8 per centum of the interior surface of the cylinder, owing to the distance at which the coils are placed apart. With the ordinary steam jacket, the heat-delivering surface is co-extensive with the interior surface of the cylinder. In fact, the Perkins system of steam jacketing cannot be considered as over one-half the efficiency of the ordinary system. The only advantage of the coil system of jacketing is the mechanical one of acting as bands or hoops around the cylinder, and thus increasing its resistance against internal pressure; but for the proper purpose of a steam jacket, which is the prevention of cylinder condensation, it is greatly inferior to the ordinary system. The water of condensation from the steam jackets, being at nearly the boiler temperature, was discharged into the condenser instead of into the boiler, and so lost nearly the heat due to the difference between the condenser and boiler temperatures.

Boiler.

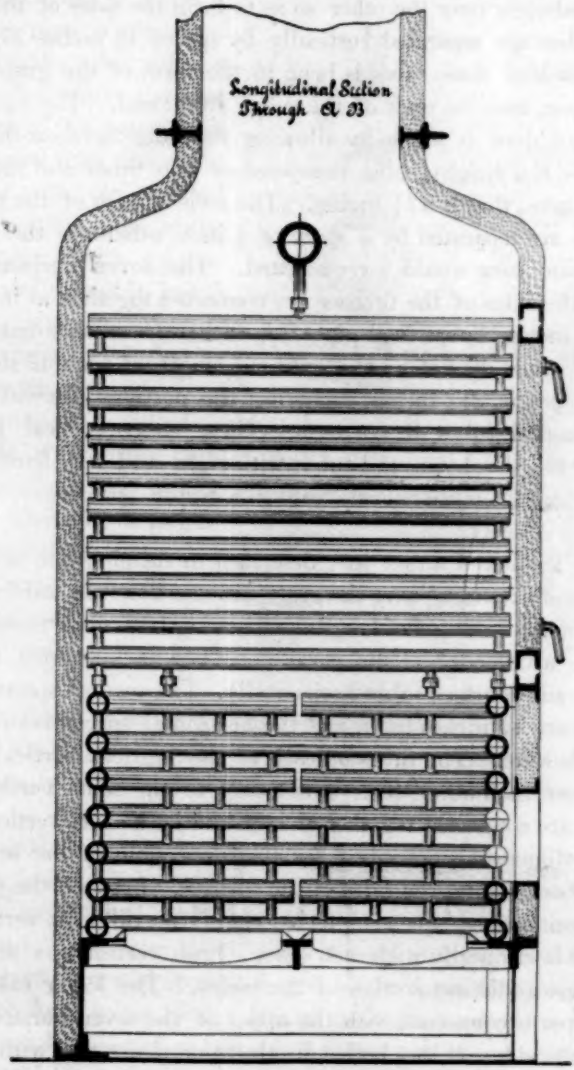
There is one boiler, and it is composed entirely of water tubes enclosed in a double shell of thin plate iron, the intervening space of which is filled with vegetable black as a non-conductor of heat. The entire thickness of the shell is 4 inches. About one-half of the tube

surface is steam generating surface, and the remaining half is steam superheating surface.



The boiler has one furnace, the grate of which is horizontal, forming a parallelogram 45¾ inches wide and 49 inches long; the corners of this parallelogram are rounded on radii of 6½ inches.

All the steam generating tubes are water tubes, that is to say, they contain the water to be converted into steam, and they are completely surrounded by the hot gases of combustion. All the superheating



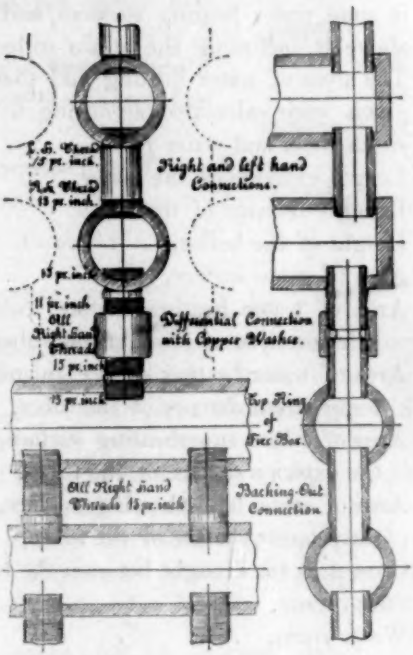
tubes contain steam and are completely surrounded by the hot gases of combustion. All the tubes, both steam generating and steam super-

heating, are of iron, 3 inches in outside diameter and $2\frac{1}{4}$ inches in inside diameter, the thickness of the metal being $\frac{3}{8}$ inch.

The grate is enclosed by horizontal tubes, seven in number, arranged one immediately over the other so as to form the sides of the furnace. These tubes are separated vertically by spaces $1\frac{3}{4}$ inches high in the clear. Each of these tubes is bent to the form of the grate which it just encloses, and the ends of the tubes are closed. The opening for the furnace door is made by allowing its width between the ends of two tubes, the height being composed of two tubes and three intervening spaces, that is $11\frac{1}{4}$ inches. The ends of each of the remaining five tubes are separated by a space of $\frac{1}{2}$ inch, otherwise the two ends of the same tube would have abutted. The seven horizontal tubes forming the sides of the furnace are connected together at intervals of about 8 inches by vertical pipes $1\frac{5}{16}$ inches in outside diameter and $\frac{1}{8}$ inch in inside diameter; the extreme length of each of these short vertical pipes is $2\frac{1}{16}$ inches, including the portions screwed into the two horizontal tubes it connects. These short vertical pipes are secured into the horizontal tubes with right and left hand threads, being screwed simultaneously into the upper and lower horizontal tubes they connect.

Above the seven tubes just described as forming the sides of the furnace, and extending over the grate, are one hundred and forty tubes, each 55 inches in extreme length and having both ends closed. These tubes are all horizontal and parallel. They are arranged ten tubes vertically and fourteen tubes horizontally. The vertical spaces between the tubes are $1\frac{3}{4}$ inches high, and the horizontal spaces between them are $\frac{3}{4}$ inch wide. The tubes of each of the fourteen vertical rows are placed over each other, their axes being in the same vertical plane, and they are connected together at each end by a short vertical pipe of the same dimensions described for the connections of the seven horizontal tubes forming the sides of the furnace. Between the ends there are no connections, nor are the tubes of the different vertical rows connected horizontally with each other. Each vertical row of ten tubes thus forms a distinct section of the boiler. The lower tube of each vertical row is connected with the upper of the seven horizontal tubes forming the sides of the boiler in the same manner as with the tube above it, namely, by a short vertical pipe at each end. The axes of the corresponding tubes of the fourteen vertical rows are in the same horizontal plane.

Above the tubes just described, and with its axis at right angles to their axes, is a steam collector composed of an iron pipe 51¾ inches in extreme length, 5 inches in outside diameter and 4 inches in inside diameter, thickness of metal ½ inch. This pipe is placed at the centre of the tubes with its axis 11 inches above the axes of the tubes of the upper row. It is connected with the tubes of each of the ten vertical rows by a vertical pipe at the centre of their length 1 5/16 in. in outside and ⅛ inch in inside diameter. The steam pipe leading to the engine, 1⅛ inches in inside diameter, proceeds from the steam collector.


Right and left hand Connections.
Differential Connection with Copper Washer.
Top Ring of Fire Box.
Backing-Out Connection.

The whole of the tubes, both those surrounding the grate and those lying above it, including the steam collecting pipe, are surrounded entirely by the hot gases of combustion, the water and steam being contained within them.

Above the steam collector the shell of the boiler is arched over, and at its centre the chimney is placed. The shell is extended below the grate sufficiently to form a closed ash pit which is provided with a door.

Large hinged doors are constructed in the shell of the boiler above the furnace door. These doors uncover, when opened, one end of each of the one hundred and forty tubes, so that they can be swept easily of soot and ash from the outside, the tubes lying in the direction of the grate bars and at right angles to the doors for sweeping.

There is no fixed water level. It can be carried anywhere at will. All the tube and pipe surface below it is steam generating surface, and all the tube and pipe surface above it, including the steam collector, is steam superheating surface. During the experiment made at the New

York navy yard with the machinery of the *Anthracite*, the water-level in the boiler was carried steadily at the top of the fourth horizontal row of the one hundred and forty tubes above the furnace. That is to say, the entire surfaces of this row of tubes and of all those below it were water heating surfaces, and the entire surfaces of all those above it, including the steam collector, were steam heating surfaces. The areas of water heating and steam heating surfaces about to be given were calculated according to this water level, as well as the steam room and water room.

Length extreme of the boiler,	5 feet 3 in.
Breadth extreme of the boiler,	4 feet 10½ in.
Height of the boiler,	9 feet 2 in.
Area of grate surface,	15·3158 sq. ft.
Area of water heating surface, calculated for the exterior circumference of the tubes,	300·24 sq. ft.
Area of water heating surface, calculated for the interior circumference of the tubes,	225·49 sq. ft.
Area of steam superheating surface, calculated for the exterior surface of the tubes,	325·89 sq. ft.
Area of steam superheating surface, calculated for the interior surface of the tubes,	239·20 sq. ft.
Cross area for draught between the tubes,	3·724 sq. ft.
Steam room,	11·048 cu. ft.
Water room,	10·109 cu. ft.

By Calculation.

Weight of tubes and their connections in boiler,	8264 pounds.
Weight of the grate bars,	728 pounds.
Weight of the ash pit,	186 pounds.
Weight of the boiler base or bearer,	380 pounds.
Weight of the chimney,	280 pounds.
Weight of the metal in the boiler casing,	1804 pounds.
Weight of vegetable black filling for the casing,	3750 pounds.
Total weight of boiler, exclusive of water,	15392 pounds.
Weight of water at 62 degrees Fahrenheit in boiler,	630 pounds.
Total weight of boiler and its contained water,	16020 pounds.

Square feet of water heating surface, calculated for exterior surface of the tubes, per square foot of grate surface,	19·6033

Square feet of water heating surface, calculated for interior surface of the tubes, per square foot of grate surface, ...	14·7227
Square feet of steam superheating surface, calculated for exterior surface of the tubes, per square foot of grate surface, ...	21·2178
Square feet of steam superheating surface, calculated for interior surface of the tubes, per square foot of grate surface, ...	15·6179
Square feet of grate surface per square foot of cross area for draught between the tubes, . .	4·1127

(To be continued.)

Crystal Palace at St. Cloud.—Plans have been prepared for a large crystal palace, to be built in the park of St. Cloud, for permanent exhibitions of industry, art, horticulture, scientific spectacles with experiments upon a large scale, together with pictures and representations of the vegetable and animal kingdom in different geological ages. There will also be views and models of ancient and modern monuments, and curiosities from all parts of the world. It is proposed to combine the attractions of the Sydenham palace, the Kensington museum and the Richmond greenhouses.—*Les Mondes.* C.

Scholastic Thermo-dynamics.—M. A. Vacant claims that nearly all the postulates of thermo-dynamics were held by the schoolmen, who taught the following facts: 1. Heat, light, electricity, weight are accidental properties of bodies and not material fluids. 2. The forces capable of producing physical phenomena may be either latent or sensible. 3. Latent forces do not undergo any transformation. 4. Sensible forces are either transformed or transmitted. 5. Forces are only transmitted in tendencies to restore equilibrium. 6. All physical forces can be transformed so as to be reproduced, according to circumstances, sometimes under the form of latent work, sometimes in that of local movement, of sound, heat, light, magnetism, electricity, weight or expansion. 7. No new force is acquired and none is lost in transformation or transmission. 8. The sum of work and of sensible movement never varies in our universe. 9. Local movement is the cause of all physical phenomena—*Rev. des Sci. Eccles.* C.

The DETERMINATION of SILICON and TITANIUM in PIG IRON AND STEEL.

By Thomas M. Drown, M.D., and Porter W. Shimer, M.E.,
Lafayette College, Easton, Pa.

Read at the Meeting of the American Institute of Mining Engineers, February, 1880.

In a communication to this Institute at the Baltimore meeting, February, 1879,* on the "Determination of Silicon in Pig Iron and Steel," the method recommended was the treatment of the metal with nitric acid until action had ceased, and then evaporating with sulphuric acid until the nitric acid was nearly or quite driven off. After filtration of the siliceous and carbonaceous residue, and washing with hot water and hydrochloric acid, a silica was obtained, on ignition, which was quite pure. Since this paper was read before the Institute, we have had large experience with the method, and find it uniformly reliable. Results are obtained in a few hours with the greatest accuracy.

While testing the method and comparing it with others in general use, and also with some new methods, there have been developed some facts which may be of sufficient value to lay before the members of the Institute.

Interesting results were obtained by the treatment of iron borings in a platinum crucible with acid potassium sulphate at a red heat. The operation must be conducted with care, to prevent too violent action; but a little practice will enable one to effect the complete oxidation of one gram of iron (the amount usually taken) in from 20 to 30 minutes. On subsequent solution of the fused mass in water, a little hydrochloric acid is added to dissolve any ferric oxide which may adhere to the crucible. For 1 gram of iron, about 25 grams of the acid potassium sulphate are used. This amount is ordinarily added at once to the iron in the crucible. The operation must, of course, be carefully watched that the mass does not flow over the top. It should not mount higher than three-fourths of the height of the crucible, which should have a capacity of not less than 70 cc. If the operation has been successful, a nearly white mass will remain in the crucible,

* Transactions, vol. vii, p. 346.

without a particle of graphite. The mass may be poured out while liquid, but a more convenient method is to insert into the fluid mass a piece of heavy platinum wire, bent at the end, and then allow the mass to solidify around it. The crucible is then slightly warmed to loosen the contents, which can be lifted out by the wire. The fused mass, with the crucible and lid, is put at once into boiling water with some hydrochloric acid. When solution is complete, the silica is filtered off and washed with hot dilute hydrochloric acid and water. After drying, the filter, with its contents, is ignited and weighed. The resulting product should be pure white. While accurate results have been obtained by this method in 45 minutes, yet a long experience with it shows that it is not to be relied on for all kinds of iron and steel. The following are some of the results obtained:

	1	2	3	4	5	6	7	8	9
Silicon by nitric and sulphuric acids	0·737	0·772	1·24	1·214	2·35	2·40	2·40	0·755	0·622
	0·739	0·777	1·25		2·37	2·42	2·40	0·757	0·629
Silicon by fusion with acid potassium sulphate	0·628	0·772	1·41		2·37	2·53	2·46	0·749	0·535
	0·677	0·702		1·250			2·47	0·761	0·566
		0·677					2·47		0·575
							2·49		0·591
							2·50		
							2·50		
							2·52		
							2·52		
							2·54		
							2·58		
							2·69		

	10	11	12	13	14	15	16	17	18
Silicon by nitric and sulphuric acids	1·92	0·207	4·40	0·165	0·929	3·75	0·027	0·682	0·205
		0·208	4·39	0·166			0·027	0·663	0·207
		0·210							
Silicon by fusion with acid potassium sulphate	1·94	0·093	4·60	0·116	0·929	3·94	0·000	0·529	0·065
	1·94	0·141		0·130		4·01	0·025	0·563	0·115
		0·231				4·02		0·598	0·120
		0·287				4·19		0·628	0·197
								0·661	0·209

1. Richmond warm-blast charcoal iron, No. 3. 2. Greenwood cold-blast charcoal, No. 1. 3. Dutchess, anthracite, No. 1. 4. Hecla cold-blast charcoal, No. 2. 5. Bushong, anthracite, No. 1. 6. Leesport, anthracite, No. 1. 7. South Easton, anthracite, No. 1. 8. Glendon, gray forge. 9. Glendon, mottled. 10. Durham, anthracite. 11. White iron. 12. Silver-gray iron. 13. Spiegeleisen. 14. Source unknown. 15. Source unknown. 16. Bessemer steel. 17. Bessemer steel. 18. Sanderson tool steel.

In the above table will be noticed many results which vary greatly from the true percentage, and for which variation no sufficient explanation is at hand. In general, it may be said that irons high in silicon give better results than those low in silicon. With silicon over one per cent., the tendency is toward too high results; with silicon under one per cent. the tendency is toward low results. When the silicon is about one-half of one per cent. or lower, the results are, moreover, very uncertain, as will be seen from the figures for mottled and white iron, also for spiegeleisen and steel. In one experiment on a sample of Bessemer steel (No. 16), no silicon was found, while, in another experiment with the same steel, made by completely driving off the free sulphuric acid from the acid sulphate, and then adding a fresh portion, the percentage of silicon obtained agreed with that by nitric and sulphuric acids. For iron or steel very low in silicon this last procedure is necessary to get even approximate results; but for ordinary pig irons, it gave no better results than were obtained by simply heating the borings with acid potassium sulphate until all traces of graphite had disappeared. Silver-gray iron is with difficulty oxidized by this method, although the results obtained from one sample were reasonably good.

For Bessemer works, where a rapid method for the determination of silicon is often desirable, this method will perhaps find a useful application. It should be mentioned that we have found great difficulty in buying acid potassium sulphate free from silica or other insoluble matter. In all cases we found it necessary to purify the sulphate by solution in water, filtration, evaporation and fusion.

Some variations were tried on the method. The pig iron was first oxidized in the crucible by nitric acid and the resulting product treated with the acid sulphate. Again, nitre was used in connection with the acid sulphate. In another series of experiments the iron was heated to redness for some time with sodium carbonate (which has the effect of oxidizing energetically the carbon and silicon),* and subsequently treated with sulphuric acid and acid sulphate. These variations were not accompanied with any better results than when the acid sulphate was alone used.

The high results are mostly caused by oxide of iron, which attaches itself in small amount to the upper part of the crucible, and which is somewhat slow of solution in acid. It does not follow that silica which is quite white after ignition is free from iron.

*Transactions, vol. vii, p. 146.

The facility with which pig iron and steel can be brought into complete solution by fusion with acid potassium sulphate will perhaps recommend this procedure when other ingredients besides silicon are to be determined.

In comparing the silicon results obtained by the nitric and sulphuric acid process with those obtained by the use of hydrochloric acid, we noticed that the results by the latter process were almost invariably higher when the residual silica obtained after burning off the carbon was not refused with alkaline carbonates. The same is true when sulphuric acid is used alone without nitric.

In many cases the silica was found to contain iron oxide or other bases, but the higher results were also obtained when the silica was found to be free from metallic oxides. Investigations showed the presence of titanic acid, and an extended series of experiments has shown that titanium is very generally present in pig iron.

In determining the titanium, Riley's method was generally used, which consists in treating the pig iron with hydrochloric acid and filtering off the siliceous graphitic residue, which is, after ignition, fused with acid potassium sulphate. This method gives fair results, but a more accurate method we found to be the treatment of pig iron in a porcelain boat in a glass tube with dry chlorine at a red heat. Pig iron thus treated is almost completely volatilized, a small carbonaceous residue—five per cent. or less—remaining in the boat. The ferric chloride, with some manganic chloride, condenses in the glass tube (which should be long enough to allow of this), and the non-metals are driven over as gaseous chlorides.

For the absorption of the silicon and titanium a series of three or four tubes or bottles of water is used. No precipitate is noticed in the water, but, on boiling, titanic acid contaminated with silica is precipitated. To determine the silica and titanic acid, the contents of the bottles are poured into an evaporating dish and strongly acidified with hydrochloric acid. Fifteen cubic centimetres of sulphuric acid (sp. gr. 1·23) are added, and the solution evaporated until all the hydrochloric acid is expelled. The silica is thus rendered insoluble and the titanic acid retained in solution, from which it can be precipitated after dilution by boiling. The results by this method are always a little higher than those obtained by Riley's method. In the treatment of pig iron by nitric and sulphuric acids, the silica obtained is free from titanic acid, which goes entirely into the filtrate. It is not possible,

however, to get more than about one-third of the total amount by precipitation by boiling, owing, doubtless, to the presence of the relatively large amount of iron in solution.

The following table shows the relation between the silicon and titanium in a few pig irons containing notable quantities of titanium:

	Glendon gray forge.	Silver-gray.	Source unknown.	Source unknown.	Leesport.	Bushong.
Titanium by Riley's method	0·099	0·114	.....	0·318	0·115	0·225
" " chlorine "	.....	0·278	0·216	0·374	.....	.....
" calculated as silicon*	0·077	0·217	0·170	0·291	0·081	0·173
Sum of last with true percentage of silicon.....	0·832	4·607	1·460	1·751	2·481	2·523
Silicon by HCl method,	0·811	4·650	1·640	1·840	2·520	2·590
without refusing.....	0·815				2·550	2·580
True percentage of silicon...	0·755	4·390	1·290	1·460	2·400	2·350

Other determinations of titanium in pig iron by Riley's method are as follows:

	Per cent. of Titanium.
Richmond, warm-blast, charcoal, No. 3,	0·018
Greenwood, cold-blast, charcoal, No. 1,	0·052
Hecla, cold-blast, charcoal, No. 2,	0·048
Dutchess, anthracite, No. 1,	0·055
Leesport, anthracite, No. 1,	0·115

A few more details of the treatment of pig iron with dry chlorine may be worth giving in the accompanying tabular form:

Pig Iron Treated.	Total percentage of residue in boat.	Siliceous residue after burning off carbon.	Percentage of carbon thus determined.	Silicon determined in this residue.	Silicon from solution in water.	Total silicon by Cl method.	Total silicon by HNO_3 and H_2SO_4 process.
South Easton.....	3·92	0·292	3·628	0·031	2·335	2·366	2·400
Glendon Gray Forge.	4·17	0·200	3·970	0·022	.....	.....	0·756
Glendon Mottled	4·29	0·302	3·988	0·015	0·444	0·459	0·622
" "	4·15	0·266	3.884	.....	.....	.....	0·622
Source unknown (1)..	4·53	0·226	4·304	0·032	0·873	0·905	0·970
" "	4·64	0·277	4·363	0·043	0·908	0·951	.....
Source unknown (2)..	4·75	0·415	4·335	0·083	1·260	1·343	1·460
" "	4·74	.....	.....	0·080	1·340	1·420	.....
" "	5·22	.....	.....	0·080	1·330	1·410	.....
" "	4·83	0·483	4·497	0·080	1·300	1·380	.....
White Iron.....	4·04	0·224	3·816	0·080	0·152	0·232	0·209
Silver-gray.....	3·38	0·240	3·140	0·045	4·090	4·135	4·400

*That is, the amount of silicon which would be calculated from the titanic acid mixed with the silica resulting from the hydrochloric acid treatment.

It will be seen from the above that the silicon is fairly accounted for in nearly all instances. A more thorough absorption of the silicon chloride by water, or, perhaps still better, by an alkaline solution, may give the full amount of silicon. As far as experiments go, there is no silicon with the condensed ferric chloride in the tube. Phosphorus is present in the ferric chloride, and sulphur is present as sulphuric acid in the water used for absorption, but we have not yet followed up these elements.

When the carbonaceous and siliceous residue in the boat is treated with water, a portion goes into solution, and in this solution may be detected, besides manganese, which we might expect, aluminum, magnesium and calcium. Whence come these latter metals? Were they present in combination with the iron, or do they simply indicate the presence of cinder in the iron?

In the portion of the residue insoluble in water these elements are likewise found, and it may be that the soluble calcium, magnesium, etc., were present alloyed with the iron, and the insoluble compounds of these metals were in the cinder. More experiments are needed to clear up this doubt.

In an experiment bearing on this point dry chlorine was passed at a red heat over cinder which had not been more than 24 hours out of the furnace, and it was found to increase in weight about 3 per cent., showing that the absorption of chlorine was not very marked. In a specimen of old cinder, the gain in weight under the same conditions was from 16 to 19 per cent. The action seemed to be the conversion of carbonates of the alkaline earths into chlorides.

When dry chlorine is passed over a mixture of a titaniferous ore and charcoal at a low red heat, titanium chloride is volatilized; but when a mixture of a blast-furnace cinder and charcoal is similarly treated, no silicon chloride is formed. It is possible, therefore, that the silicon remaining in the boat after the treatment of pig iron by chlorine may result from the presence of cinder in the iron. More experiments are needed before any decided assertion can be made on this point.

It was expected that the treatment of pig iron by chlorine at a low red heat would give a separation of iron from manganese. We were unsuccessful in effecting this separation. In all cases, some manganese was found with the ferric chloride. With spiegeleisen, or ferro-

manganese, the fusion of the manganic chloride in the boat rendered it difficult to volatilize all the iron.

In the paper previously alluded to on the determination of silicon, it was stated that in the treatment of pig iron by hydrochloric acid about one-third of the silicon was found in solution and two-thirds in the residue. Further experiments have shown that the relative amounts of silicon in solution and in the residue depend on the strength of the hydrochloric acid. Thus, in an iron containing 0·738 per cent. of silicon we found in the insoluble residue, after treating with hydrochloric acid, as follows:

With acid of sp. gr.	1·20,	0·616
" "	1·12,	0·440
" "	1·015,	0·006

Again in an iron with 2·36 per cent. of silicon we found:

With acid of sp. gr.	1·20,	2·26
" "	1·12,	2·05
" "	1·015,	0·02

There is no loss of silicon by volatilization in treating gray or white iron with hydrochloric acid.

Influence of Temperature on Tuning Forks.—Kayser finds that the number of vibrations of a tuning fork between 9° and 30° (32° and 86°F.) is a linear function of the temperature; the influence of temperature increases with the sharpness of the note, the variation for one degree being sensibly proportional to the square root of the number of vibrations. Within the limits named the coefficient of atmospheric elasticity increases with the temperature.—*Les Mondes.* C.

Uniformity of Vegetable Composition.—H. Pellet has continued his investigation upon vegetable composition by analyzing numerous specimens of potatoes. He finds that there is a constant ratio between the total amount of phosphoric acid contained in the entire plant and the starch; there is a similar ratio between the starch and the mineral substances which are absorbed, exclusive of silica; there are great differences in the proportions of the principal alkalies, but the quantity of sulphuric acid necessary to saturate all the bases is sensibly the same.—*Comptes Rendus.* C.

AN ADAPTATION OF BESSEMER PLANT TO THE BASIC PROCESS.

By A. L. HOLLEY, Memb. Inst. Civ. Eng., etc.

THE BASIC PROCESS.

The process of dephosphorizing iron in the Bessemer converter, held in this country under patents of Thomas, Snelus and Riley, is called, by common consent, the Basic Process.

In the ordinary Bessemer operation, when the flame "drops," as observed by the naked eye, or when the carbon lines disappear, as more accurately observed through the spectroscope, there still remain in the metal some hundredths of a per cent. of carbon, also of silicon, also all the phosphorus which the metal originally contained. Further blowing would oxidize the iron itself. But if the slag in the converter, instead of being acid (chiefly silica), as in the ordinary operation, is basic (chiefly lime), a small part of the phosphorus will be found in the slag, instead of in the metal, when the flame drops. And if the blowing is further continued for two or three minutes, all the phosphorus, excepting a few hundredths, will be found in the slag, and the iron will not have been much oxidized; it will have been protected by the phosphorus. Chemists disagree as to the precise reactions which occur; we suppose that phosphorus is always oxidized by the air blast, and that it constantly returns to the iron, in presence of an acid slag; we know that a basic slag retains the phosphorus, however it may have got it.

The basic process, therefore, consists of two things: First, the maintenance of a basic slag; second, the "afterblow."

First. The basic slag is *formed* by the addition of about twenty per cent. of lime to the iron charge in the converter before or during the blowing. The basic slag is *maintained* chiefly by making the converter lining of lime, and also by using iron low in silicon. An acid lining would be destroyed by the lime additions, and would vitiate the slag. The latter result would be produced also by silica formed by the oxidation of the silicon in the iron. The grand difficulty has been the limited durability of the basic lining. After much costly experimenting, practicable linings have been made of dolomite bricks

—bricks formed by wetting and moulding pulverized magnesian limestone and then burned at the highest attainable temperature. The magnesia prevents the bricks from crumbling when exposed to the air. Linings are also formed by ramming hard-burned, pulverized dolomite, mixed with ten per cent. of tar, into the converter. Ordinary fire-brick tuyeres are used in lime bottoms, or the bottoms are rammed around rods which form tuyere-holes.

Second. The afterblow presents little difficulty; its duration is soon determined for any grade of material and products.

In order that the phosphorus may be thoroughly removed—it seems rather paradoxical to say—there must be plenty of it. Silicon, the chief heat-giver in the ordinary process, must, as we have seen, be kept low. Phosphorus is also a heat-giver, but there must be enough of it to maintain, by its combustion, perfect fluidity in nearly pure iron. At a lower temperature the Bessemer process could not be completed. Iron best adapted to the basic process has two to two and one-half per cent. of phosphorus and under one per cent. of silicon, also one and one-half to two and one-half per cent. of manganese—a heat-giver and a valuable ingredient in steel—but the manganese may be dispensed with at this stage of the operation. The afterblow completely removes silicon and reduces other impurities.

Spiegeleisen, or ferro-manganese, are added to the blown metal, but most of the slag is first poured out of the converter, so that the manganese shall not carry the phosphorus out of the slag to the iron. Otherwise the process is conducted in the usual manner.

In nearly all parts of the United States there are phosphoric ores adapted to the basic process. They are usually cheap, and in some regions, of the South especially, they are so abundant, and so associated with coal and limestone, that the manufacture of cheap steel is likely to become, in such localities, a vast and important industry.

The maintenance of refractory linings in Bessemer converters, in such a way as to promote regular and maximum production, has been the subject of more experimenting than any other feature of the Bessemer system, and it is still the least perfect and satisfactory feature, excepting perhaps the casting of steel. Linings are not only eroded by the mechanical action of the charge, but they are chemically decomposed by its various slags. The silica linings usually employed have, indeed, been so improved that an average of say sixty charges per twenty-four hours can be got out of a pair of converters, and the

shifting of interchangeable converter bottoms (containing the tuyeres) is so rapid that it does not delay production; but the repairing of the fixed lining just above the tuyeres, where both mechanical and chemical action are most severe, is frequently the cause of delay, and the operation rapidly performed between heats is tedious and costly. The accumulations of slag on other parts of the lining must also be quarried out, else the converter will become too small for the charge.

These are the conditions of maintaining silica linings; but the difficulties are increased, probably about threefold, when the linings are made of lime, for the basic process. The basic process consists in removing phosphorus from the iron under treatment by retaining the phosphorus oxidized by the blast, in a basic slag formed of say twenty per cent. of lime added to the charge. An acid (silica) lining would vitiate the basic slag, and would also be rapidly destroyed by it. Lime containing some magnesia, and produced by burning magnesian limestone (dolomite), is at present the only basic material successfully used for converter linings. It is usually made into bricks, which are hard burned and built up with mortar of similar material to form the lining.

Basic bottoms and tuyeres stand ten to fifteen charges, nearly equaling acid bottoms, and they may be readily changed; but basic linings, near the tuyeres, and also in other parts where abrasion is severe, wear rapidly and must be frequently repaired by cooling the converter and inserting new bricks, or patching in some suitable manner. The converter is thus put out of use for at least twenty-four hours—a very serious delay to production. From a wide observation, the author feels safe in saying that a basic lining is rarely run above sixty charges without extensive repairs, and in some works repairs are made every time a bottom is set. With some irons there is also an accumulation of slag around the mouth of the converter; its removal sometimes also causes further delay.

The output of a pair of converters in Europe averages about half that of a pair of converters of the same size in the United States, and is often less than half. The limited endurance of basic linings in Europe is, therefore, a less conspicuous defect than it is here, where one converter must make 25 or 30 charges in twenty-four hours, so that the repairs of basic linings, as at present conducted, would keep an American plant idle half the time. This delay is really as impor-

tant in Europe as it is here; the greater the output from a given plant, the cheaper the product.*

In order, therefore, that the basic process may come into extensive use, basic linings must be so maintained that their output will nearly equal that of acid linings.

There are two reasonable conditions of improvement: the one is to prolong the endurance of basic materials, so that their repairs can be made with little delay, while the converter is in position for use. There seems to be little or no progress, or probability of immediate progress in this direction. The other is the rapid and complete removal of a worn lining and the replacement of a repaired one. A third system, seriously proposed, is to double or treble the entire converting plant. The only practicable way to replace a refractory lining (which cannot be handled by itself) is to replace the vessel which contains it. The worn portions of the lining may thus be repaired at leisure, in another part of the works, rather than in position for use, where repairs would retard output.

An obvious way to replace an entire converter lining is to replace the entire converter. This system is already under construction in Europe. The method is also obvious—lifting the converter bodily out of its pillow blocks, and conveying it to the repair shed by means of an overhead traveler; then setting a repaired converter in place by the same means. Such a plant is doubtless cheaper than a duplicate plant, and its output should be materially greater than that of fixed converters. But the operation of changing an entire converter must be slow and tedious. When the arrangement is such that pillow block caps are required, these must be loosened by unscrewing heavy nuts; then they must be made fast to the crane chain, lifted, traversed and set down. The blast pipe connection must be broken, and possibly some platforms must be removed. Then the traveler is placed exactly centrally over the converter, ponderous chains are made fast, the mass is raised high enough to clear surrounding parts, and drawn laterally to the repair shed; then the converter is placed centrally over its seat and lowered and steadied (as it swings from a chain) into its pillow

* The statement sometimes made in England that the rapid production in America impairs quality of product is but a cover for inadequate plant. Steel is obviously no better because five hours instead of one are consumed in setting a vessel bottom, or because it may take twice as long in an English works to handle materials and product.

blocks. The repaired converter is raised, traversed and set in place by repeating all these operations; the blast connection is then made, and the pillow block caps are lifted, traversed, steadied into place and screwed down. If the converter is removed in sections, transferring each section and making the refractory joints will occupy much more time. The chimneys and the openings in the side of the building must be high enough to make passage not only for the traveler but for the converter when lifted out of its seat, and for the chains that sustain it. A traveler of the required power, height and length is obviously a ponderous and costly structure, and to work with reasonable speed it must have independent steam power—the hydraulic system of the works cannot well reach it.

The method of replacing the lining proposed by the author, and shown in the engravings, is *removing only the shell* of the converter; lowering it out of the trunnion ring easily and rapidly, by means of a simple lift and car, and replacing a repaired shell by the same means. No pillow block caps, blast connections, nor other surrounding parts are touched; a dozen cotters are knocked out, the shell is lowered and run straight back to the repair shed, the new shell is run in, lifted and cottered on; this is all. The machinery and transference are on the general level, and not forty feet or more up in the air. The car may be moved by a small reversing engine or by a hydraulic capstan, by means of a wire rope and sheaves suitably arranged. The car runs against a stop, and the lift is perfectly vertical, so that the shell may be put in place by two rapid motions without the delay of adjustment.

The lining may be heated before the shell is put in place, and bottoms (and tuyeres) may be separately removed, as at present, or they may be taken away with the shell and repaired without removal from it. In the latter case, the shell must be placed in trunnions, in the repair shed, so that the bottom may be turned downward for repairs. But if the bottom is first removed, the shell need not be placed in trunnions in the repair shed; the shell will stand mouth downward on the car, a position most favorable for repairing both the mouth and the lining about the tuyeres, which are the two places chiefly needing repairs. This is doubtless the better plan, and it saves the cost of supplementary trunnion rings and turning gear. The engravings show the converter hung so high above the general level that the bottom and tuyere box can be hauled out, with the shell, under the trunnion ring. In case

the bottom is previously removed, the converter may be hung some three feet lower.

It has been remarked that in American works converter bottoms are changed so rapidly that one is always ready, even when tuyeres stand but eight or ten operations. Changing converter shells is much more rapid than changing bottoms. The several operations of removal and transportation are the same, but the converter lining must be trimmed out to receive the new bottom, and a refractory joint must be made. The new shell has merely to be cottered on.

The comparative cheapness of apparatus to change the shell, instead of the entire converter, is obvious. The two hydraulic lifts for removing the bottoms are made heavier, and there are several cars of simple construction; this is the entire extra apparatus. The increased cost of the converters is not important. In the other case, the traveler with its engine, and the standards and turning gear in the repair shed, and the trunnion rings and pinions (the chief cost of the converters) for each spare shell, approach in expense that of a duplicate plant complete.

But one objection has been raised, as far as the author is aware, to the plan proposed, and that is the possibility of damage to the lift under the converter, in case the charge should burn through and fall upon it. To avoid such damage, the lift table may be sunk several inches below the pit level and covered with sand. It may be remarked that lifts under converters are used in nearly all the American works with satisfactory results.

The engravings illustrate the construction and arrangement so fully that little explanation is required. The trunnion ring (Figs. 1 to 4) is of cast iron, with an inch wrought iron lining; or it may better be a steel casting, which will not require a lining. There is a two-inch annular space between the trunnion ring and the converter shell, and the shell is prevented from shifting laterally by means of the wedges shown in Fig. 1. The car is raised by the lift to receive the shell; or the shell may be lowered by means of a fork on the lift passing through the car.

This construction of converters has led the way to a general improvement in the design of the plant. The shells and bottoms may be run out laterally into the converting house, but the space here is insufficient for convenient repairs, and the shells for one converter could not be well got to the other. In order that there may be one

common place for repairs, and ample room both for spare shells and spare bottoms, they must be run out in rear of the converters, as shown in Fig. 8. If blast furnace metal is brought directly to the converters this rear space is not otherwise wanted; but if cupolas are placed there, as is usually the case, they must be so arranged that the shells can pass out under them.

But the cupolas (excepting the spiegel cupolas) may best be placed elsewhere; if there are blast furnaces the cupolas may be so arranged near them as to utilize the same system of transportation, hoisting, blowing and hot blast. There should be plenty of spare gas from good furnaces to heat cupola blast. These are very important considerations, regarding both cost of plant and economy of working; and, judging from the experience at many works, the disadvantages of hauling fluid iron some thousands of feet in a railway ladle are less than those due to crowding the melting department and its stock yard and appurtenances, close behind the converters. Fluid iron is hauled from one to two miles* without chilling; it need usually be hauled but a few hundred feet, and the cost of the transporting plant and service should be about the same for the two systems. There are two important advantages in the arrangement shown by the engravings:

1. Placing only the spiegel cupolas, instead of the entire melting department, close behind the converting house leaves its rear comparatively open to free ventilation, thus cooling not only the space around the converters, but also the casting pit.

2. This arrangement provides ample room for the convenient removal of slag, which, in the basic process, is very voluminous; one long dumping car placed under both the converter and the ladle catches it all, and as the bottom of the pit is on the general level, the slag is neither handled nor lifted; the car is simply hauled out by the yard locomotive and dumped. Experts well know the cost and inconvenience of breaking up and quenching slag in the pit, and of lifting it out of the pit, and then loading and removing it.

Iron may be got to the converters in a ladle by various means. It may be hauled on the general level to one or more hoists, and run into short spouts or directly into the converter mouths, or it may be drawn up a gradual incline or lifted by a hoist to an elevated railway near the converters, and thence tipped or tapped into them directly or

* At the Barrow Works it is hauled two miles; at Ebbw Vale some five miles.

through spouts. The short elevated railway, as shown in Fig 7, has one conspicuous advantage—it is out of the way of all other apparatus and operations; it does not cross railways nor interfere with any transportation on the general level. This is an important feature when a charge is made every 20 to 30 minutes. The ladle is drawn by a locomotive to short, steep spouts leading to the converters; there is no lateral or hand movement, and hence no delay. A spout leads to each converter, chiefly for the purpose of leaving the space between the converters (where the common spout is usually placed) quite free for the spiegel ladle.

The spiegel cupolas and their appurtenances occupy so little room that they are placed, without interference with other apparatus, very near and above the converters. A railway ladle receives the spiegel from either cupola and tips it directly into the converter, quickly and hence completely, by a short run and without hoisting or lateral movement. It may be weighed in transit if desired. The wide platform between the converters is at other times free for bringing lime, scrap or other materials to the converter mouths, and these materials are conveniently raised by the cupola hoist.

The floor of the converting house is raised a few feet, so that the pit bottom may be on the general level, for the convenient removal of slag, as before explained. The ground outside of the converting house slopes gradually to the general level. This facilitates the removal of products and also the drainage.

The plant for repairing shells consists of two turn tables, some short railways and a shed; also some platforms and a lift for materials. If bottoms are to be removed with the shells there must also be mounted trunnion rings and turning gear; also a crane in the shed; but, as before explained, this seems unnecessary. Room is shown for repairing four shells at a time, but the railways may be lengthened to accommodate more. The plant for repairing bottoms consists of short railways and turn tables, a space for ramming bottoms under a shed and the necessary ovens for drying them; also a crane, which sets the bottoms directly on the oven cars. If ordinary tuyeres are used fewer ovens are required; if the bottom is all one tuyere, rammed around rods, it must be burned for two or three days, so that more and hotter ovens are necessary. The repairing department may obviously be arranged in other ways to suit special cases.

The average output of the American plant, having two 6-ton to 7-

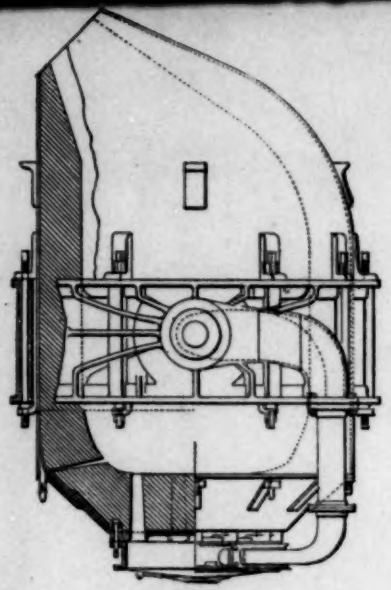


Fig. 1.

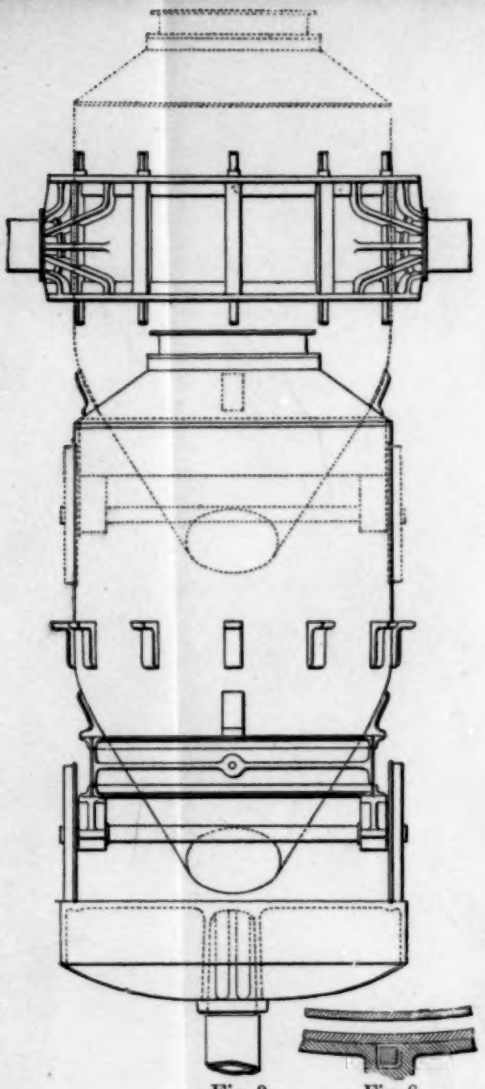


Fig. 3.

Fig. 6.

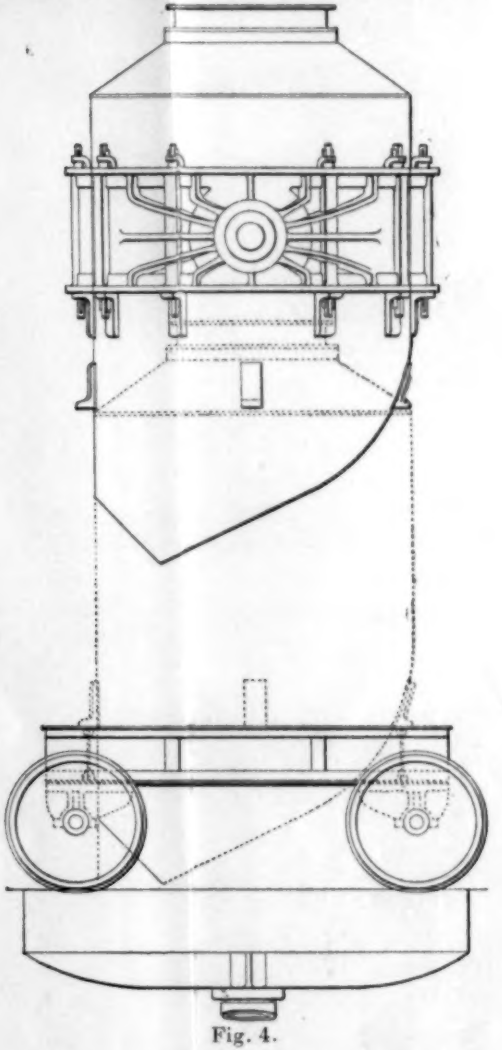


Fig. 4.

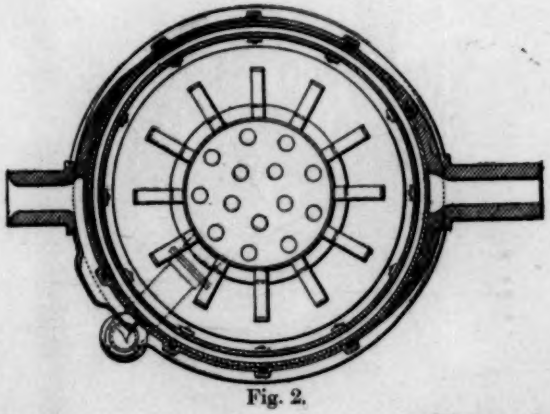


Fig. 2.

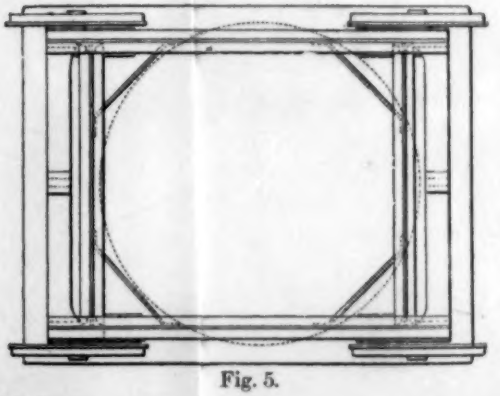


Fig. 5.

HOLLEY'S CONVERTING PLANT FOR THE BASIC PROCESS.

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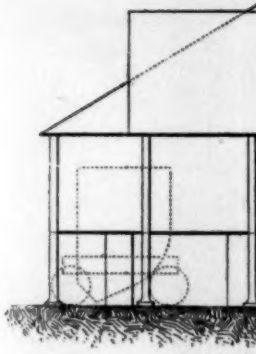


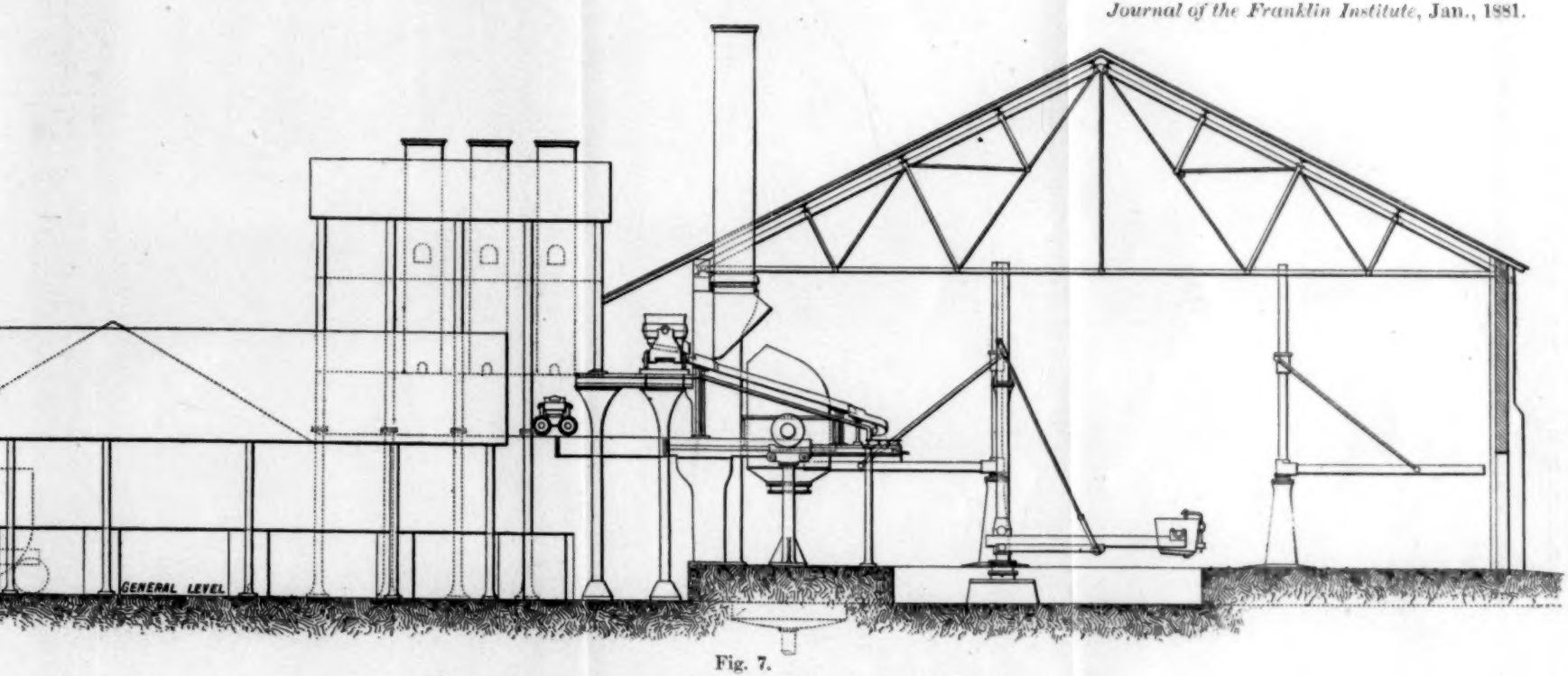
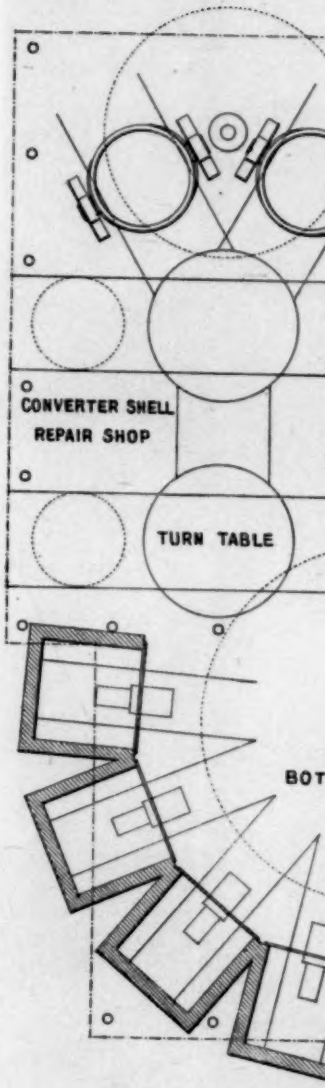


Fig. 7.

HOLLEY'S CONVERTING PLANT FOR THE BASIC PROCESS.


CONVERTER SHELL
REPAIR SHOP
TURN TABLE
BOT

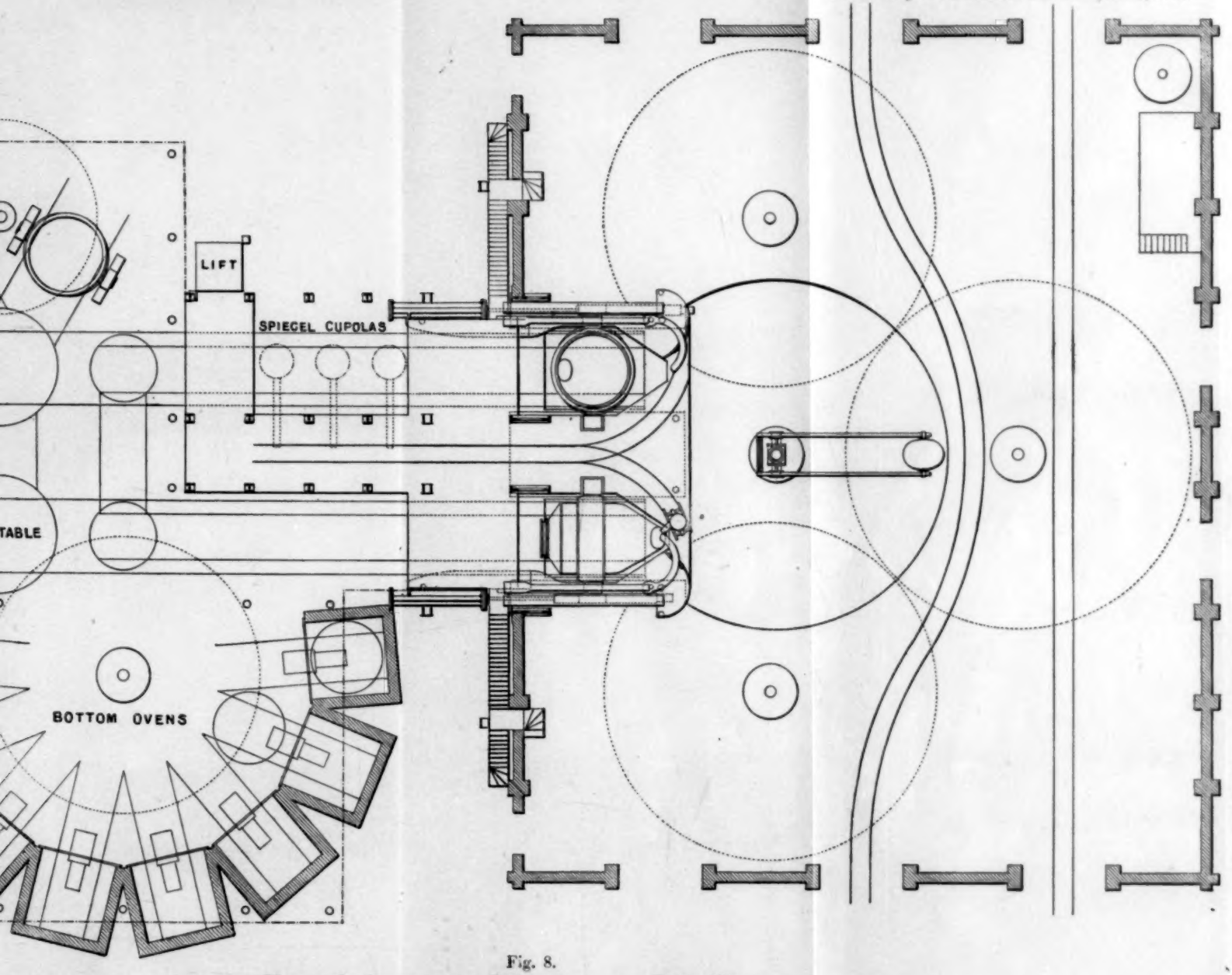
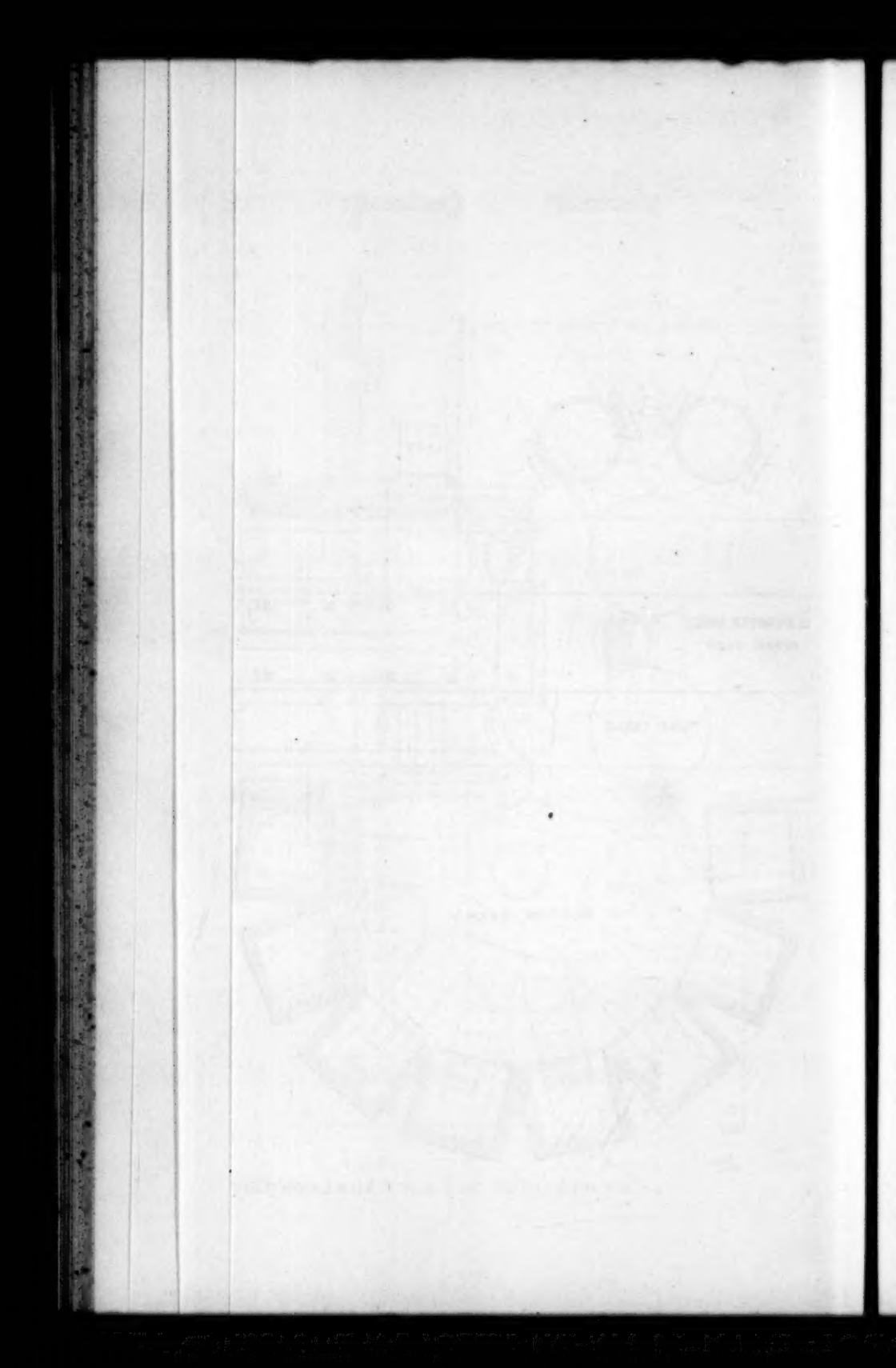


Fig. 8.
HOLLEY'S CONVERTING PLANT FOR THE BASIC PROCESS.



ton silica lined converters in one pit, is 100,000 tons of ingots per year. It will doubtless appear that the plant under consideration should produce even more, with basic linings, because it has 10-ton converters, and means of keeping one of them in constant repair, so that the converting operations may follow one another without interruption.

Recapitulation.—1. The endurance of basic linings is so small that the ordinary system of repairs would reduce the output of an American plant about one-half.

2. The only adequate system of repairs, with existing basic refractory materials, is to remove and replace linings bodily by removing and replacing the vessels containing them.

3. Changing converters, trunnions and all requires very costly apparatus, and much labor and time in disconnecting parts and in making the transference.

4. Changing only the shells of converters (leaving the trunnions and their connections undisturbed) requires only cheap and simple apparatus, and the operation may be performed so quickly that basic linings will give the maximum output of acid linings.

5. Leaving the building open in rear of the converters, instead of placing the melting department there, gives good ventilation and ample space for bottoms and shells to be run out for repairs and for slag to be removed from the pit. The cupolas (excepting the spiegel cupolas) may be placed elsewhere, especially by adjacent blast furnaces; and melted metal may be transported thousands of feet without difficulty.

6. Placing the pit bottom on the general level allows slag to be hauled away directly, without rehandling or lifting. The elevation of the converting house floor thus produced facilitates the removal of products.

7. The metal ladles are brought in behind and above the converters, and are discharged by separate spouts, so as to leave the space between the converters open for a short run of the spiegel ladle, and of lime and other solid materials to be charged.

8. The spiegel cupolas are placed near and above the converters, so that the metal may be run in quickly and completely, without vertical or lateral movement, by means of a ladle car.

9. The repairing plant is conveniently placed in rear of the converting house, but it may obviously be modified in extent and position, to suit local circumstances.

THE VALUE OF THE STUDY OF THE MECHANICAL THEORY OF HEAT.

By Alfred R. Wolff, M.E.

A Paper read before the American Society of Mechanical Engineers, Nov. 5th, 1880.

In presenting a few remarks on the value of the study of the mechanical theory of heat, I am imbued with the knowledge of two facts: of the importance and value of the study on the one hand, and of, in general, a lack of proper appreciation among engineers of this point on the other. There are doubtless few among educated engineers who would not admit that the acquisition of any form of knowledge is of value, not only as a training of the mind but as an addition to our understanding of the laws and working of the universe and mankind; few who would deny that the study of literature, of social or politico-economic sciences would be of benefit to them, though of limited influence in the practice of their profession.

From personal experience, as well as from the experience of others, I am lead to believe that engineers, as a class, look upon the knowledge of the mechanical theory of heat not much unlike than that of the department of "belles-lettres," as possibly adding to refinement, to a broader view of things in general, to a fair drilling of the mind, but of no practical or only slight practical value in the ordinary, or even extraordinary, exercise of their profession. I am not prepared to say that were the grounds above enumerated the only ones upon which the study could be urged, that a strong argument in favor of its more general introduction could not justly be maintained; but this question does not arise since the more general introduction of the science can be presented to the engineer on the ground of direct, practical utility, for the purposes of correctly appreciating and increasing the efficiency of a large department of his profession, that department which treats of the transformation of the latent or active forces or powers of nature in a form suitable for application as motive power for utilization in machinery designed to do the desired special work, or, in other words, to that department which relates to the generation of the working fluid or motive power, and the work performed by the medium of such fluids in prime movers. It is on this ground that I

would urge the more general acquisition of the science of thermo-dynamics, and to insure conciseness as well as a ready conception of my views, I will only briefly outline the thoughts, giving as it were their direction, and leave it to you to give them force, that is, to develop them more fully as your own understanding and experience will best suggest.

Thermo-dynamics or the mechanical theory of heat is, as the name implies, the science of the laws of heat considered as a form of energy. It is based upon two great, general laws, the one that all forms of energy are mutually convertible in certain exact, invariable equivalents, the other that the quantity of energy in a homogeneous substance is equal to the sum of the energy of its component parts, and that equal parts of a homogeneous substance when undergoing a change of, or exerting, energy undergo like changes, and exert like effects. The application of these two fundamental laws of energetics to heat constitute the determination of the two general laws of thermo-dynamics, which are the basis of the whole science, and of which the science is in fact but an extension and application to forms of heat energy, latent or active, met with in nature and valuable in practice. For after all what is theory but practice reduced to a connected system of laws or principles. Without facts, without phenomena, in short, without practice as a foundation, how could theory ever be conceived or established? In ordinary discussion but little attention is paid to the distinction between theory and hypothesis, and nothing has proved more disastrous to a general appreciation of theory than the repeated misuse of the term. Theory is based on facts, hypothesis on speculation, hypothesis changes to theory when speculation changes to facts. The two special laws of thermo-dynamics, upon which the whole science is elaborated, to which we refer are: that heat is convertible to other forms of energy in the relation of what is known as Joule's equivalent, that is, that one thermal unit (the quantity of heat required to raise one pound of water at 39·4° Fahr., one degree in temperature) is equal to the energy required to raise 772 lbs. 1 foot, or that 772 lbs. falling 1 foot will develop sufficient heat to raise 1 lb. of water at its greatest density 1 degree. The second is that if the total actual heat of a homogeneous and uniformly hot body undergo a change or exert energy, equal parts of the body will undergo equal changes and exert like effects, the sum of the effects of the component parts being equal to the total effect. This law is more popularly identified in the

form of Carnot's theorem, a special application to heat engines, that $q - q_1$ or $\frac{T - T_1}{T}$ is the limit of efficiency of such engines, and that the test of a perfect engine is its reversibility. q and T represent respectively the quantity of heat and absolute temperature of the (any) fluid when leaving the generator, and q_1 and T_1, respectively, the quantity of heat and absolute temperature of the fluid when given off to the refrigerator: q—q, when entirely converted into useful work causing the engine to become theoretically perfect.

The above outlines the foundation and framework of a great science. It is strong and simple, and in its strength and simplicity beautiful. The structure and superstructure are equally strong, equally beautiful, but not, however, equally simple. If this were the case there would be little need of the presentation of papers of this kind, for the great value of the science would be universally acknowledged. It is a common experience that the mass of mankind primarily pronounce that which is difficult to attain as not worthy of attainment, primarily too often look upon those who have mastered the difficult with scornful or doubting eye, until the achievement of the difficulty by the few has brought forward such valuable results, such striking truths, so influences the ordinary experiences and our conception of facts in nature or in our professions, that the worthiness and value of the attainment can no longer be denied and must be definitely accepted. That point has now undeniably been reached in thermo-dynamics, and the sooner we concede it the better. The sooner we admit that we must study and explore the science of heat energy in its higher form, the sooner will we advance in our profession and contribute to its progress. It will be my aim to recall a few of the practical applications in engineering of the principles which thermo-dynamics has established, and thus to give an illustration or rather indication of its value. But before doing so to be strictly conscientious, I must refer to the difficulties to be met with in the study in its higher form. Professor McCulloch says: "Any one acquainted with only the elements of analytical geometry, and of the fluxional calculus, should find no difficulty in understanding all it contains. In this country, however, scientific education, as well as classical, has unfortunately retrograded; and superficiality is the fashion of the day. Hence, some anxious for scientific knowledge, with the least labor and in the shortest time, imagine it might be well in scientific literature to dispense with the calculus. To them

no better advice can be given than to begin by studying it thoroughly, if they would reasonably hope ever to comprehend much which would otherwise be unintelligible."

These elements, however, must be firmly fixed in the mind, and thermo-dynamics may justly be considered a thorough test of such a knowledge. When beginning the study of the subject, I thought I had fairly mastered calculus, while engaged in its acquisition I found I was a mere novice, and such too has been the experience of a few of my friends who have already progressed and done good work in the science. But let us not be deterred from the acquisition of a valuable subject because of its difficulty. This really incites a person to a hard effort, and the gratification which the mastering of an important point gives, forms an incentive to further advance which acts more potently than the repulsive part of the difficulty. Let us not accept the valuable principles reached without making at least an honest effort to follow the masters who have discovered them, and thus make the principles in reality our own. But if our comprehension and efforts will not permit us to do this, let us not cry down the methods by which they were attained, and let us study the principles themselves thoroughly.

There is a wonderful harmony in nature—without it all scientific research would be of no avail. There are certain great invariable laws, some determined and many more not yet conceived, but in our faith in and knowledge of the reliability of those laws exists the only safeguard of advance. This opens up that large realm of reasoning known as "by analogy," and enables us to determine thus, and by analysis, laws which are not directly determinable from our practical experiences or observed phenomena. Heat, the observed and usually acknowledged primary physical source of all energy (though gravitation might on some good grounds be selected as our present ultimatum) beautifully illustrates this harmony when considered as energy, and thus prescribes laws which are afterwards verified in practice, and to which practice conforms and becomes the embodiment of. This is the strongest plea which it seems to me can be urged for the careful study of the mechanical theory of heat, and we will attempt to point out some of the work which has been done in this respect, and leave it to your judgment to decide whether a science which has already accomplished so much is not capable, when many able minds are devoted to its study, of an application and extension which is and will be of

incomprehensible value in the ordinary practice of the engineer, and which will greatly contribute to the advance of mechanical engineering.

The specific heat at a constant pressure of any permanent gas can be ascertained directly by experiment, not so the specific heat at constant volume. Regnault has made accurate determinations of the specific heat of such gases at constant pressure, and discovered certain laws relative to the same, that the specific heat of such a gas is independent of its temperature and density, and the product of the density and the specific heat is the same constant for all permanent gases. From the velocity of sound, independent of the principles of thermodynamics, the specific heat at constant volume for a permanent gas can be determined, and these two quantities when substituted in an equation of the theoretical value of the mechanical equivalent of heat, expressed as a function of the pressure, volume, dilatability and the two specific heats of a permanent gas give for this equivalent a theoretical value which agrees with that practically determined by Joule, and recently verified by Professor Rowland. I need not dwell upon the mathematical exposition of this, but reference to Stewart ("Elementary Treatise on Heat," pages 330 and 412), Maxwell ("Theory of Heat," pages 169, 228, and 310), Cotterill ("The Steam Engine considered as a Heat Machine," page 82), McCulloch ("Mechanical Theory of Heat," page 92), and Rankine ("Steam Engine," page 321) will serve as a verification of the above summation. Permit me to call your attention to this remarkable agreement between theory and practice. The specific heat at constant volume is not directly determinable from experiment, so it is developed from the velocity of sound, and substituting these two independent experimental data (the two specific heats) in a theoretical equation not involving a previous determination of the mechanical equivalent of heat, we ascertain such equivalent from correct theoretical considerations, and it accords with the experimental determination. What a beautiful correlation of the different laws and facts of nature do we here perceive exemplified.

But this will appear rather as an illustration of the beauty and symmetry of the science than as a presentation of a fact of direct utility to the engineer in the practice of his profession, and since it is my special object to call attention to a few of the latter class of facts, I will have to omit the mention of the interesting relations between the physical properties of bodies, such as between the two elasticities and the two specific heats, gaseous viscosity and the molecular theory of the

constitution of bodies, all of which the science teaches and will at once refer to its main application for our own purposes, the work of fluids in engines. It is in this department of our profession that thermodynamics has made the deepest impression in practice, and is destined to continue it to a far greater extent. It has taught us the different laws of expansion and work of fluids, and has supplied us with the proper test of the efficiency of different forms of engines. $\frac{T - T_1}{T}$, the limit of efficiency has enabled us to correctly appreciate the progress made, and to definitely point out the direction in which the advance in efficiency and perfection of heat engines lies. To increase the theoretical efficiency, T, the temperature of the fluid at its entrance to the cylinder should be raised, and T_1, the temperature at exhaust lowered as much as possible.

The application of this principle to steam engines implies high steam pressures and great expansion. This was tried within certain limits, and the beneficial results looked for were not realized to the extent expected. The theory was still recognized as true by those who grasped it, but the practical result had not conformed to their expectations. The nature, laws and action of steam were thoroughly investigated, and it became apparent that condensation ensued, owing to heat consumed for internal work during expansion and to the detrimental action of the metal of the cylinder. When the steam enters the cylinder (of a lower temperature than the steam at its initial pressure) it gives out heat to the metal of the cylinder, and to do this sets free latent heat, causing water of condensation to be formed. When the steam in the cylinder expands it performs internal as well as external work, and becomes partially liquefied; as the steam leaves the cylinder, rushing into the condenser, the water mixed with the steam evaporates, abstracting additional heat from the metal of the cylinder. When a fresh volume of steam of initial pressure now enters the cylinder it comes in contact with the metal of lower temperature, water of condensation is formed and the action continues as indicated above.

Several methods of decreasing this loss presented themselves:

1. The introduction of the compound engine which dividing up the range of temperature between admission and final exhaust, in two or more stages, causes less difference in each cylinder, and therefore decreases the loss by condensation while again the heat abstracted from the first cylinder at exhaust becomes available in the second cylinder.

2. The use of the steam jacket which tends to keep the metal of the cylinder at uniform temperature and thus prevent the initial condensation of steam, and to supply heat to the steam in the cylinder to prevent condensation during expansion.

3. The introduction of a great number of strokes per minute so that less time will be accorded to the steam to impart heat to the metal of the cylinder and to abstract heat during exhaust.

4. The use of superheated steam, since it can emit heat when being admitted to a cylinder of lower temperature without causing water of condensation to form at entrance or during expansion.

Neither of the first three remedies proved entirely efficacious in practice while all have greatly reduced the loss from condensation. An intelligent study of the theory of heat will show, however, that the latter is the only one which offers the possibility of entirely preventing condensation. Perhaps it will need some explanation why the steam jacket can never entirely prevent this loss. It is owing to the fact that the transfer of heat from the steam in the jacket is not as rapid as the transfer of the heat from the internal sides of the cylinder to the steam in cylinder, that the steam on entering the cylinder heats up but a small thickness of metal to its own temperature, owing to the comparatively poor power of conduction of iron. And the steam in the jacket, similarly, heats up to its own temperature but a small thickness of the metal of the cylinder immediately in contact with it; in brief, the poor heat-conducting power of iron does not allow the transfer of heat from the steam in jacket to the steam in cylinder to be practically instantaneous.

There may be some who are opposed to the introduction of the high speed (as they are popularly termed) or rather "high revolution" engines. But whatever be their practical defects—and they possess some mechanical advantages that we are inclined to think more than counter-balance those defects—the principle is in the right direction, and already splendid workmanship and refinement of mechanism and machinery tends to confirm the value theory accords the system.

We will now briefly refer to the use of air. Thermo-dynamics demonstrates its superiority to steam. Its permanently gaseous nature enables it to expand without doing internal work, and its temperature can be raised to a high degree without the objection of a high pressure difficult to control. But practically the few air engines built have as yet not proved a decided success, owing to the difficulty of obtaining

a rapid conduction of heat to and from the air employed, and the necessity of a larger cylinder than is needed for a steam engine of the same power. Again, very high temperatures of the air cause no inconsiderable strains due to irregular expansion of the metal and a slow oxidation of the metal as well. And so with other forms of fluid engines. Practical difficulties and obstacles have not always permitted the rigid teachings of thermo-dynamics to be precisely realized, though they have in most cases served as an exemplification of its truth. But as long as we have the laws of the mechanical theory of heat to teach us where the possibility of or road to progress lies, better steam and better air and better gas and better fluid engines will in time be built. Even with the fluids and materials at present known, the performances of engines are capable of being doubled, a result by no means too trival to make an honest effort to master the principles which will aid us in securing this end. But who would dare to say in an age when Professor Crookes' fourth state of matter opens up realms of investigation undreamt of, and when Professor Bell's discovery of sound transmitting rays of light potently reminds us that we are but at the threshold of our understanding of the laws of the universe, who would dare to say that new fluids, materials and conditions will not be discovered that will enable us to extend the limits of temperature between which the fluid can expand in a cylinder, and thus utilize by far the greater portion of the latent power which nature has presented to us in her stores of fuel!

But it may be said: The advances, pointed out above, in the efficiency of engines have not in all cases been instituted by those who have mastered the mechanical theory of heat, and the advances, therefore, are not in all cases the result of the study of the subject. This is partially true, that is while, as far as I can learn, no advances have been secured in the efficiency of heat engines (not including, of course, reduction of friction and better mechanism for transforming the rectilinear motion of the piston) by men who have not been intimately acquainted with, at least, the fundamental principles of heat energy, they have not in all cases mastered the whole subject in its highest mathematical form. But to correctly appreciate and define the advance, the theory of heat energy has always been called into play, and if our progress in the efficiency of heat engines has not been as rapid as we might have desired, and is not as rapid at the present time as desirable, it is owing to a lack of knowledge and understanding of the subject

under discussion by some of our more brilliant and experienced minds. There are two methods of gaining knowledge. One by acquiring the laws and results of the experience of others, the other by acquiring the laws by our own experience. Both constitute the acquisition of principles or theory. Both have their uses. But it is a loss of time and it is at the expense of many failures and disappointments which do not contribute to real advance, if we arrive at the same principles by such failures that others have reached before us, by whose experience we might have profited. When we have acquired the knowledge of the work that others have done, we are prepared to make further progress, and if the difficulties and obstacles multiply we will be fairly equipped and fully encouraged to meet them. If we then experience failures, they will contribute to real advance instead of demonstrating a fact or law which had already been acknowledged, and which it was within our power and province to know. Thus too will indorsement of, and investment of capital in, prime movers, advertised as realizing fabulous power be avoided, since our knowledge of the laws of thermo-dynamics will have acquainted us with the principles of the conservation of energy, the impossibility of transgressing certain limits, and will, therefore indicate or demonstrate the fallacies of the projected scheme.

In conclusion, I must say that I am aware that full justice has not been done to the theme under discussion, nor can, in my opinion, full justice be done to so grand a theme within the limits of a paper of this kind. A complete treatise would have to be written to demonstrate its true importance, and some work like that of Rankine is the best verification of the actual value of the science, and in its study does this value become most potently apparent.

But if I have been able to convince—say, one of you, heretofore uninterested, of the *vitality* of the study, I will feel amply compensated, and will offer no apology for my enthusiasm in the cause.

American Watches.—The Waltham Watch Co. has received an order from the British government for 372 watches, to be distributed among the railroad officials in India. This being the third order to the same company is a satisfactory evidence of the esteem in which the watches are held abroad. In each instance the British government advertised for proposals, and the American firm distanced all competitors.—*Fortschr. der Zeit.* C.

BLASTING.

By ARTHUR KIRK.

Paper read before the Engineers' Society of Western Pennsylvania, Oct. 19th, 1880.

In this age of improvement I know of no important industry in which so much hard labor and money is lost for want of intelligent study and use of modern improvements as in the simple operation of blasting.

When you bear in mind the fact that blasting of minerals lies at the very foundation of all that distinguishes civilized from barbarous life, you will at once admit that its importance makes it well worthy of our attention.

You are all aware that the houses of civilized men are very much superior to those of the barbarous races. The first point of difference is in the foundation, and almost the first things needed for the foundation of a house for civilized man are powder and blasting to get stone for the foundation.

Another point of superiority of civilized life is the abundance of manufactured iron and glass, yet I think that not one pound of all the immense quantities of these articles manufactured around Pittsburgh is obtained without drilling and blasting to prepare either the coal, iron ore, limestone or sand used in its manufacture. But the very nature of the work of quarrying seems to draw to it many men of one idea who work hard and think little; who having made holes in rocks for many years, insist, therefore, that they know all about blasting and persistently oppose all modern improvements.

Many farmers are living yet who have cut many harvests with a sickle before the days of cradles, mowing and reaping machines, etc. These might with the same propriety resist the use of mowing and reaping machines because they know all about farming.

Another reason why improvements are not introduced in blasting is because the owners of mines seldom give any personal attention to blasting, but leave it all to others, who seldom take any interest in improvements, and are often prejudiced against them and condemn them without a trial.

The subject of blasting may be divided into three divisions:

1st. The hole and how to make it.

2d. The explosive used.

3d. The manner of firing the charge.

1st. *The Hole and How to Make It.*—The common way of making the hole is by either churn or jumper hand-drills. Three men usually form a gang, and the gang make from eight to twelve lineal feet of hole per day in hard rock.

By either of these modes it is practically impossible to make a round hole—generally a three-cornered hole being made, which is very objectionable—because, if the hole is perfectly round it will present a uniform circular surface to the pressure, and retain the blast until its force is fully developed. But with a three-cornered hole the pressure on the long sides of the hole is concentrated at the corners, which, being required to resist more than their share of the pressure, give way and permit the explosive gases to escape before their force is fully developed, and only a large amount of smoke is produced.

A much better plan is to have the holes made by machinery; this secures a cheaper and better hole, being perfectly round, and thus retains the explosive gases until their power is perfectly developed, and do more execution on the rock and with less smoke. In close or underground work, where the air is bad, this is found to be of great advantage. With the latest improved steam drills a gang of three men often make from seventy-five to one hundred feet of hole in one day.

2d. *The Explosive Used.*—Explosives may be divided into chemical and mechanical combinations.

Chemical explosives embrace what are known as nitro-glycerine, gun cotton, dynamite, dualin, hercules, Ditmore powder, rend rock, mica powder, etc.

These are produced mainly by the combination of nitric acid, sulphuric acid, and fatty matter or glycerine, with cotton, tan bark, paper pulp, sawdust, soda, mica scales, pulverized charcoal, etc., as absorbents.

These will explode under water, which makes an excellent tamping. Most of them are unfit for sporting or military use, because their explosion is so instantaneous it ruptures the gun before the ball can start. Their force is more like the blow of a large sledge, whose force is spent in an instant, while the explosion of black powder is more like the action of a powerful spring, which starts the projectile more

slowly and continues to propel it until it escapes at the muzzle of the gun.

The manufacture of chemical explosives is of comparatively recent date, and in many cases is as yet imperfectly understood. Many alarming accidents have occurred in the handling of some of them, which has given a bad name to the whole family. But enough is now known about some of them to prove them to be perfectly safe when properly understood and handled, and very profitable in certain kinds of blasting.

Mechanically combined explosives are common black powder, carbo-azoteen and mahoning powder.

These are composed mainly of saltpetre or nitrate of soda, sulphur and charcoal, or tan bark.

All of these ingredients are first finely pulverized separately, and then mixed in certain proportions, and incorporated by being run under heavy wheels or rollers for from two to six hours, so as to mix uniformly and bring a certain proportion of each ingredient in immediate contact with the other ingredients.

The mass is then generally submitted to strong hydraulic or screw pressure, and then is called pressed cake. Then it is crushed by corrugated rollers, and by means of sieves separated into the different sized grains of blasting, sporting or military powder, each of which has its peculiar mark or name.

Carbo-azoteen is made by boiling these ingredients together, and has never been a success.

Mechanically combined explosives must be kept perfectly dry; even a slight degree of dampness injures them.

As a rule, the finer the grain the quicker the explosion and the smaller the charge; while for large blasts in rock, powder is now used to good advantage in grains as large as grains of corn, and in large artillery charges still larger grains are used, called Pebble Powder. We now come to the

3d. *Mode of Firing the Charge.*—Three modes are used—squib, fuse and electricity. Squibs are made of about six inches of rye straw, filled with fine powder, and are used principally in coal blasting. The hole being drilled horizontally three to five feet into the coal a charge of eight to twelve inches of FF blasting powder is generally put in, then an iron rod $\frac{5}{16}$ inch in diameter, called a needle, is

inserted in the hole back to the powder, then the hole is tamped full by having dry clay or sand pounded solid into it, and the needle is withdrawn, leaving an open passage like a pipe through the tamping to the powder. The squib is inserted in the mouth of this hole, and a slow match applied to the outside end; the recoil of the powder burning in the straw throws the burning squib back along the needle hole or pipe to the powder chamber, and the explosion takes place. This mode of firing can only be used in horizontal holes.

Fuse consists of a thread of black powder incased in a wrapping of tarred hemp, and called hemp fuse—or in a wrapping of cotton, and called cotton fuse; then, to make it waterproof, a tarred tape is wrapped spirally around it, and then it is called single tape fuse, and will resist dampness a long time; or a double wrapping of tarred tape is wrapped around it, and called double tape fuse, which will burn and fire a charge of powder under 20 feet of water.

In all of these fuses there is a central cotton thread, which has been saturated with saltpetre, which makes it continue to burn when it would otherwise go out. Every precaution is taken to make the fuse continue to burn until the fire reaches the powder and the explosion is produced. But, from some cause or another, holes sometimes hang fire, and are a source of great danger to the miner or quarryman. Holes thus charged, which ordinarily should explode in from one to three minutes, have been known to hang fire for twenty-four hours and then explode.

The third mode of firing is by electricity. When using it, the hole, the charge and the tamping are the same as in firing with a fuse, but, instead of inserting the common fuse already described, an electric exploder is used, which is made thus:

A copper cap, $\frac{1}{4}$ inch diameter and about 1 inch long, is filled $\frac{1}{3}$ full of fulminate of mercury, into which is inserted the ends of two insulated copper wires connected by a small thread of platinum wire, and the end of the cap is then closed by means of melted sulphur, making it waterproof. Electric fuses are made 4, 6, 10 and 15 feet long, with about two inches of the outer end stripped of the insulation and tinned.

In using them the blaster selects an electric fuse long enough to reach the bottom of the hole and leave a few inches of wire out of the hole, then puts in enough powder to cover the bottom of the hole $\frac{1}{2}$

inch deep, then his exploder, then one-fourth less powder than if fired with a fuse, and tamps the hole the same as with ordinary fuse; any number of holes may be thus prepared of equal or unequal depth or distances apart.

Directions for Firing.—One wire of the first hole is now connected to one wire of the second hole, and the remaining wire of the second to one wire of the third hole, and so on until all are connected; there will then be one wire of the last hole and one wire of the first hole left unconnected. These wires are then connected by means of long conducting wires to the battery at a place of safety, and when everything is ready the circuit is closed and the small thread of platinum wire in the bottom of each hole becomes red hot and each cap is exploded with great force at the same instant, and each hole assists its neighbor. And thus by simultaneous explosion, with only three-quarters of the powder used in ordinary fuse blasting, more than double the rock is moved with the same drilling.

In quarries where fuse is used it is not uncommon to find six inches or a foot, or even two feet of the bottom of the holes remaining unruptured after the blast has been fired and cleared away—the drilling of the unexploded piece of hole was so much hard labor lost, and the powder it contained was lost, for if the powder had done what was intended no part of the hole would have been left unexploded. No part of the hole is thus left unexploded where electricity is used, because in firing by electricity the first point ruptured is at the bottom of the hole, and the full force of all the explosive is spent in enlarging the rupture.

For profitable blasting by either mode of firing, the bottom of the hole in open work should be at least one-tenth less from the open front of the rock than the depth of the hole; thus, if the hole is ten feet deep, the bottom of the hole should not be more than nine feet from the face of the rock, and in some rock not more than eight feet, so as to make the bottom of the hole the weakest part of the blast. But if the hole is ten feet deep and filled up four feet with powder, and fired with a fuse at the top of the powder, there will only be six feet of rock on the top of the first point of rupture, and there being nine feet in front of the hole makes the top the weakest part, and the result is a great discharge of projectiles through the air, to the great danger of all around, and much of the material is lost; but if the

same single hole had been fired by electricity at the bottom of the hole, the bottom rock would have been forced out, and the top rocks would tumble down and do no damage, and all be in place to be handled.

The contrast between firing with a squib and by electricity is still greater, because a fuse may sometimes burn to the bottom of the hole before firing the blast, but a squib must always fire at the top of the powder, and as the needle hole is a full quarter inch in diameter, the first blast is a jet of orange flame from the needle hole, which is partly consumed powder, and cools into dense smoke, to the great annoyance of the miner; in light work, only the top is blown off the hole, the first point of rupture taking place at the top of the powder.

In conclusion, to show this is not idle theory, but actual fact, I may point to the shaft sunk this summer for the Chicago and Connellsville Coke Company, near Uniontown, under the superintendence of Mr. James Harrison.

Mr. Harrison has had great experience in everything connected with modern mining improvements, and on commencing work on the shaft procured the latest and best improved steam rock drill, an electro-magneto battery and safe chemical explosives, and with the assistance of Mr. Thomas, an experienced Welsh shaft sinker, he broke ground about the 15th of last March, and two weeks ago he had sunk the shaft 325 feet to the coal; has got his ovens and all his buildings up, and I presume is now making coke, which under the old plan of sinking he could not have done before next April.

I can also point to the shaft now being sunk by Mr. J. K. Taggart for E. K. Hyndman, near Connellsville, and to another near the same place, now being sunk by Mr. Hopkins for Mr. Wickham, of Connellsville, both of whom are using electricity and chemical explosives to good advantage.

I may further add that theoretically blasting by electricity has been known to engineers for thirty or forty years, for large blasts such as Hellgate. But it has only been within the last few years that the apparatus has been made so simple and portable as to be of any practical benefit in quarry work. It has now been made so simple, and is so easily handled, that a youth can take the apparatus out of the tool box, lay down the cable to a safe place, charge five or six holes, tamp and fire them, and take up the cable and replace apparatus in tool box, all inside of ten minutes.

ON THE WHOLESOMENESS OF DRINKING WATER.

By Reuben Haines.

Abstract of a Lecture delivered before the Franklin Institute, December 9th, 1880.

It was only about thirty years ago that cholera epidemics were discovered to be largely due to the transmission of the disease from one person to another by means of water used for drinking. This disease is unquestionably transmitted also in other ways, as for example, by the atmosphere; but that water is one of them, and in some countries the most important one, the vital statistics of England prove beyond a doubt. I say, in some countries, not in all; for it appears that the evidence in Germany, which seems to have been very thoroughly investigated, is against the theory of the carriage by water of the cholera poison in such a way as to cause infection. Pettenkofer, the celebrated sanitary authority of Germany, is entirely opposed to this view. Nevertheless, in England, India, Holland, and a few localities in Germany, the evidence appears overwhelming. Dr. Parkes states that while we should give proper deference to the evidence in Germany and Austria, we should not allow it to outweigh the evidence from other countries.

It has also been found that typhoid fever has been spread through towns and smaller communities and through separate households by carriage of the infection by drinking-water. So many instances of this have become known that it may be considered proved beyond all possible doubt to be a fact, and one which is generally and not merely exceptionally true.

It is true, however, that typhoid fever, like cholera, may be transmitted also by the air; and there can be no question that the gases or vapors emanating from sewers and drains and breathed in a confined atmosphere are a very frequent means of transmitting the disease.

Dr. Parkes states, in the latest edition of his work, that the question which is the most important or frequent means of infection, air or water, cannot yet be answered. Dysentery has been long known to be caused partly by bad water. There is considerable evidence to show that water may transmit diphtheria, but not sufficient to prove it with

certainty, except perhaps some evidence in Massachusetts which is very strong.

When the water in any of these cases has been examined by chemical tests it has generally been found to have organic matter either dissolved up in it or suspended in it. Frequently this material has been found so entirely dissolved as not to be detected by the eye; that is to say, water which was clear, colorless, free from anything visible, except a very few floating particles and which even had a good, refreshing taste, was found on careful examination of all the circumstances to be without the slightest doubt the real cause of the spread of typhoid fever and cholera from one person to another.

Water, on the other hand, which is pure or free from any contamination with human sewage, in any part of its history in past or present time, has never been proved to be the means of infection with such diseases as cholera and typhoid fever. But diseases of other sorts have been caused by mineral matters dissolved in the water or by vegetable matter held in suspension, while the water was nevertheless entirely free from sewage contamination.

Water, then, which is impure, is to be dreaded as a frequent cause of disease. But in what does this impurity consist and how are we to distinguish the two sorts of impurity I have mentioned? We will understand this better if we first carefully consider what constitutes a naturally pure water and which is found, by wide experience, to be perfectly wholesome and should be our daily drink.

Those who have studied chemistry are aware that absolutely pure water is composed of one part by weight of hydrogen to eight parts by weight of oxygen, or, by volume, of two parts of the former to one part of the latter. Chemically pure water contains nothing else whatever. But such water does not exist in nature, nor can it probably be produced in the chemical laboratory, for the purest distilled water, redistilled many times, is found, perhaps invariably, to contain exceedingly minute traces of ammonia and on standing a few hours it absorbs oxygen and nitrogen from the air to which it is exposed.

When, therefore, we speak of a pure, wholesome water we do not mean water which is chemically pure, but one which is as free from foreign substances as is to be found under the most favorable natural conditions.

We should consider all natural water found either on or below the surface of the ground as having been originally precipitated out of the

atmosphere in the form of rain, snow, hail, fog or dew. Of these, rain and snow are obviously the most important, and these in falling carry down with them a part of whatever may be either naturally or abnormally present in the atmosphere. Now, we know by practical experience that the atmosphere in high situations is generally purer than on level plains or in low places. When our bodies are in need of an invigorating atmosphere we go to the mountains, and those who have traveled in mountainous regions often speak of the delightful effects experienced, provided they do not enter too rare an atmosphere. Chemical analysis confirms this impression. The atmosphere of the mountain is generally really purer than that of the valley at its foot.

Rain collected near the surface of the earth will, therefore, be more impure than that collected at a considerable height, because of the greater impurity of the air near the surface of the ground. After the elapse of a short time the rain water will be much purer than during the first part of the time of rainfall.

The purest air of the mountain regions contains, besides nitrogen and oxygen, a small proportion of carbonic acid in the free state and still smaller amounts of ammonia combined with carbonic acid, nitric acid and nitrous acid. Besides these, there is found also a very small amount of organic matter suspended in the air, probably dead or effete matter swept up by currents from living animals and from vegetation in decay. The amount of this organic dust becomes less and less as we ascend to greater heights, while the proportion of carbonic acid becomes somewhat increased. All of these various gaseous and solid substances are therefore to be found in rain water. Since a part of the rain goes to form springs, we find these substances in the purest spring-waters; but here they exist in a somewhat different form from that which they had in rain. Water in passing through the ground always comes in contact with some substances capable of dissolving more or less in it.

Water in its purest state may be said to be an almost universal solvent. Give it sufficient time and the proper temperature and atmospheric pressure and it will dissolve an appreciable amount of the most insoluble substances. This effect will take place much more readily when the water contains certain saline substances, especially nitrates and chlorides. When rain water has carried down from the atmosphere salts of ammonia, even if in very minute amounts, its solvent power on soil and rock is thereby increased, and this increase will be

in some proportion to the amount of impurity washed out of the atmosphere.

The soil itself is known to contain carbonic acid in its pores in much larger proportion to the other gases than exists in the atmosphere. Carbonic acid, we all know, is soluble in water in greater amount, according to the pressure, as is well shown in the soda-water fountain. This gas when dissolved in water has a great solvent power on limestone rock, and when the carbonic acid gas escapes again by evaporation the water leaves those beautiful pendant stony icicles which we find in limestone caves like the Mammoth Cave of Kentucky and which we see on a very small scale on the arched roof of many stone bridges, where they are formed from the mortar between the stones of the arch. In fact, the caves themselves are thought to be formed by this solvent action. Lime is a part of the material of many other kinds of rocks beside limestone and of the soil resulting from their disintegration. The gaseous carbonic acid of the soil added to that already in the rain and to the nitrous and nitric acids in combination with ammonia also found in it, dissolve a part of the lime and other mineral matter of the soil and rock, and when this soluble mineral matter is in large amount a mineral spring is formed thereby or simply an ordinary limestone spring, as the case may be. In either case the water is called "hard." If the rock is of insoluble material like granite or gneiss, only a very small part of it is dissolved, and in this case a soft spring water is formed. Yet even in granitic regions the water may be hard, owing to such substances as sulphate of lime in the soil above the rock being dissolved in it. This is to a certain extent the case in Germantown, where some of the uncontaminated wells furnish quite a hard water while others give very soft water.

All soils contain more or less organic matter derived from vegetable and animal matter in decay. Some of this will necessarily go into solution and pass into the spring water; but it appears that some spring waters contain less organic matter than the rain from which they are derived, so that there is possibly a filtering action going on in the soil in these cases. In the majority of cases, however, it is probable and in many cases, it is certain, that a proportion of the organic material of the soil is added to that already in the rain. The amount of organic matter in soil and rock varies according to its geological nature. Thus, such rocks as the granitic series contain almost no organic matter, while sands and gravels, sometimes thought very free from it,

generally contain considerable amounts of it, and occasionally in so large amounts as to cause the well waters to be decidedly injurious. Dr. Parkes mentions as an instance of this the district in the South of France called the "Landes," where the sandy soil contains so much as to cause water of that region to produce malarial fever.

Alluvial soil, or that deposited by the floods of rivers and streams, contains very frequently large amounts of organic matter which passes into springs and wells and renders them unwholesome.

Waters from marshes are well known to contain large amounts of vegetable organic matter, so as often to prove extremely unwholesome. The case of the ship *Argo*, sailing in 1834 from Algiers to Marseilles, may be mentioned as a very strong instance in proof of this.

Water coming from peat bogs is often highly colored with dissolved peaty matter. This peaty matter appears to be very different from the vegetable matter found in marsh water in not being in a state of actual decomposition, but being material which has in the solid state become partially carbonized and undergone thereby a change preparatory to becoming coal. Hence a number of chemists and sanitary officers have of late years strongly protested against the condemnation of peaty waters on the same grounds as marsh waters, declaring this to be a great mistake. It must be admitted by every candid student of this subject that some waters, which experience has proved to be very wholesome, originate in peat bogs and contain in the state used for drinking very considerable amounts of nitrogenous organic matter in solution, and there is evidence to show that this material is mainly of vegetable origin.

Let us now consider the effects produced on the health by the mineral matter commonly present in ordinary spring and river waters under entirely natural conditions. While we can positively say that our present knowledge does not warrant the assertion that any one of a number of these mineral substances have any injurious influence upon the health, it is nevertheless obviously true that a large excess of lime and magnesium salts, such as carbonates, sulphates and chlorides, are undoubtedly unwholesome in many instances.

Waters which contain these salts of lime and magnesia are called "hard" in consequence of their action on soap. The great waste of soap caused by these waters as well as their injurious influence in the boiling of meats and vegetables are matters of considerable importance in domestic economy. The soap waste and the tendency to

form incrustations in boilers are facts of vast importance to the manufacturer, but these considerations we will postpone for the present.

While dyspepsia and other internal maladies have undoubtedly been traced to the drinking of water containing large amounts of these salts and while goitre and cretinism occur in close connection with, and some affirm, are caused by magnesian limestone waters, there seems to be still a decided disagreement among sanitary authorities as to the wholesomeness of a moderately hard water. Hardness, however, which is due chiefly to sulphate of magnesia, would seem certainly undesirable on several accounts.

From these circumstances it will appear evident that the purest water naturally contains some appreciable amounts of mineral matter, and a water which does not contain it in too large amount, the limit of which has not been satisfactorily settled, may correctly be considered, so far as this is concerned, a perfectly pure water from a strictly sanitary point of view.

Finally, from this whole discussion it is clearly seen that a hygienically pure water must be defined as one which may contain naturally foreign substances, both mineral and organic, in small amounts; but if the organic matter is in larger amounts it must not be in a state of decay or decomposition or capable of readily undergoing such changes.

Further consideration will lead us to modify this statement in so far as to add, that a pure water must also contain nothing which would leave a suspicion upon the mind of a probable present or future contamination with sewage.

Some authorities would add that it also must contain no evidence of contamination with sewage *in any past time.* This is the position which Dr. Edward Frankland takes; but I think we may reasonably dissent from so severe a decision, which would exclude all our river waters as too dangerous for public supply. The chief reason for dissenting is that the premises upon which he founds his conclusions have not been clearly proven, indeed, they are directly disputed by other chemists.

We have heretofore considered water as it exists under wholly natural conditions. We will now consider it as these conditions are influenced by man's occupations and habits which are consequences or accompaniments of civilized life, and interpose circumstances more or less artificial.

We have noticed the influence which the natural atmosphere has on

the chemical condition of rain water. What is now the effect of the atmosphere surrounding communities of men?

The atmosphere of cities and towns is rendered impure by the gases, smoke and soot issuing from the chimneys of houses and factories; by the dust from the streets, which is to a great extent organic; by particles of all sorts of clothing, hair, skin and refuse material from every trade; organic matter from the breath and persons of men and animals; and also by the gases resulting from decomposition of organic matter such as garbage and filth usually left for some time in places where it should not be at all, and the gases arising from stagnant sewers.

Rain, in falling through such an atmosphere, will wash down these gases and organic dust, thereby rendering the atmosphere more fit to dwell in. But the rain water itself will be exceedingly impure, and, indeed, so foul as to be entirely undrinkable without nausea. Beside the organic matter, nitric, sulphuric and muriatic acids, in the free state as well as combined, are found in such rain in considerable amount, which will vary greatly. In addition to the effete or dead organic matter we find also in the air minute forms of animal and vegetable life. Nevertheless, the air of well ventilated streets, even in large cities, is much purer than we might expect. The percentage of oxygen in many streets in the less crowded parts of London, that is to say, outside of the limits of old London, was found very slightly less, and the percentage of carbonic acid very slightly greater, than the natural amount on open land.

Rain falling in suburban towns will, of course, be much purer than that of cities; but where the houses are situated near much-traveled streets, dust composed largely of organic matter will be deposited on the roof, and the rain water collected from this will contain considerable impurity.

If the gutters and pipes placed to carry the water into cisterns, or the cisterns themselves, are made of lead or zinc, these metals will be dissolved by the water so as to render the cistern water poisonous to drink. This corroding action is commonly much more rapid with rain water than with ordinary spring water.

If we pass on to the consideration of other kinds of drinking water, we find that streams, ponds and rivers, all of which are used for this purpose, contain the dissolved manure from cultivated fields, and the filthy and often very poisonous drainage from factories of

various kinds, besides those which make use of chemicals in their processes of manufacture. In addition to these, a most important source of impurity, and wherein lies probably by far the greatest danger, is the sewage of cities and towns situated along the banks of rivers or lakes used for drinking water, or on streams draining into them. Frequent reference is made to the solid impurities, such as wool factory refuse, floating on the surface, but any one who is acquainted with the methods used for cleansing the raw wool knows the disgusting character of the materials used for this purpose, enormous volumes of which are poured into the river after the operation is finished, and which are probably entirely unseen because dissolved in the water. It may be said, however, that much of this organic stuff may be entirely decomposed and destroyed before it passes through the water mains and is delivered to consumers. We hear frequent remarks made on the impropriety and danger of allowing cemeteries of large extent, like Laurel Hill, to drain into a river water used for drinking. The dangers arising from this source may, however, be said to be infinitesimal as compared with the direct drainage of human bowel excreta into the river by means of city sewers. The peculiar dangers of sewage contamination of public water supplies will be more clearly understood as we discuss the subject in subsequent lectures of this course.

Wells are the chief source of drinking water in country and suburban districts, and in towns having no public water supply. Artesian wells of great depth are sometimes used for city supply, but these are found unsatisfactory, because they do not meet the demands of an increasing population, and at the same time generally furnish a very hard water.

Deep wells, or those over 100 feet in depth, but not artesian, are seldom used for private domestic purposes, yet these are strongly advocated by high sanitary authorities, as furnishing the best supply for domestic use where a "driven" tube well cannot be sunk. The chief object is to go below and to exclude carefully the water in the upper water-bearing strata, which will be very liable to become impure. The wells generally used are less than fifty feet deep, and very frequently both these wells and the vaults and sinks for sewage are generally placed tolerably near the house, and also near each other. Often in small lots, and sometimes in larger ones, the cesspools or privies and wells are not more than ten feet apart. Ash and garbage heaps, in a state of fœtid decomposition, are frequently placed quite close to the well. All

this has been found actually true in various parts of England, and in Massachusetts.

As might be expected, numerous cases of typhoid fever were the immediate cause of the investigations that were made. Not only in Massachusetts is such culpable negligence to be found, but also in many other parts of this country, and as near home as the immediate neighborhood of Philadelphia. The recent investigations of the Massachusetts State Board of Health into the sanitary condition of hotels and boarding-houses at various summer resorts of that State has brought to light a large number of cases of most astonishing ignorance and criminal negligence in this respect on the part of both hotel proprietors and smaller householders. Some of the cases discovered on the island of Martha's Vineyard were so bad that it is difficult indeed to believe that any person would knowingly subject himself to such dangerous surroundings.

Dr. Joseph G. Pinkham, in his very able and thorough official report, in 1876, on the sanitary condition of Lynn, Mass., himself a resident of that town, makes the following remarks:

"The most erroneous ideas in regard to the liability of wells to contamination prevail among the people. Those who are familiar with the principles of under-drainage by means of porous earthen tiles know that when they are placed in the earth the water will find its way, for quite a long distance on either side to them and through their pores; yet they are only small vacant spaces in the earth, while a well is a large and deep one, attracting moisture from a much greater distance. But, notwithstanding these well known facts, persons of high intelligence on most points feel perfectly secure in regard to their wells with a cesspool or privy within a few feet of them."

In regard to other sanitary conditions, Dr. Pinkham remarks:

"Less than one-tenth part of the families, shops, etc., supplied with the city water have drains connecting with the sewers."

He estimates that drainage water to the amount of 420,000,000 gallons are annually absorbed by the soil of this town, and then he asks the reader to form his own opinion as to the probability of this foul drainage soaking into the thousands of wells situated in this same thickly settled part of the town. There is but one possible answer to the question. It is but right to add that what was true of this town in 1876 may be very much improved now, but of this I have seen no positive statement.

We know very well that any hole or ditch acts as a drain to the earth surrounding it. A well, as ordinarily constructed, is precisely such a hole for drainage. Any contaminating liquid, or any solid matter capable of being dissolved and washed into the soil by the rain; any such material as human sewage placed or allowed to flow on the surface of the ground near the well, will be exceedingly liable to pass directly into the well water. In other words, it will help feed that well, and a considerable amount of sewage escaping filtration will eventually be daily consumed by the people of the house in their drinking water.

This is certainly not a pleasant subject to contemplate, but it will do us no possible good to shut our eyes to a state of things which actually exists, and which is every day liable to cause disease and death in our families.

The more loose the soil in which the well is dug, that is to say, the more sandy and gravelly it is, the more liable the well is to contamination. It has been stated by some writers that a well drains a mass of soil in the shape of an inverted cone whose apex is the bottom of the well and whose base is an area of surface having a diameter equal to three times the depth of the well. That is, a well of 20 feet deep will drain an area 60 feet in diameter or any liquid within 30 feet of the well will be liable to pass directly into it. This statement is necessarily a very rough estimate, since the area of surface drained will vary exceedingly according to the character of the soil. There is clear and positive evidence to show that in sandy and gravelly soils the extent of drainage area is far greater, even when the surface of the ground is level and the stratification of soil is quite horizontal. In New England the Massachusetts State Board of Health Reports give a number of instances where pollution of wells from cesspools situated in sandy level soil to the distance of more than 100 feet from the wells. The water was found by chemical analysis to be polluted with sewage and cases of typhoid fever occurred from the use of such water for drinking.

If contamination takes place in level soil to the distance of 100 feet it will undoubtedly be liable to occur at much greater distances when the soil and rock are inclined towards the well. Mr. Child, Officer of Health for Oxfordshire, England, gives in one of his reports an instance of the fouling of wells by petroleum or benzine which passed through the soil from a broken barrel buried in the ground to a num-

ber of wells all of which were from 250 to 300 yards distant. The surface of the ground had a descent of about 60 feet between the two points toward the wells. About 82 people living in 15 houses were unable to use these wells for ten days and cattle refused to drink from one of them. In commenting on this remarkable case we should recollect the extraordinary penetrating power of petroleum oils. We can scarcely believe that sewage can be carried through nearly the sixth of a mile of soil as the petroleum was in this case. Nevertheless it furnishes a very good text for a sermon on the possibilities of sewage contamination.

Sand and gravel at first undoubtedly exert a certain amount of filtering power. But this is soon exhausted by the soil becoming saturated with filth, and in course of time a direct channel may be opened to the well through which the sewage may sometimes pass unobstructed even in the solid condition.

From these facts we can positively say that a sandy and gravelly subsoil is one of the most dangerous of all situations for a shallow well in a thickly settled neighborhood, or where the cesspools and privies are not placed at the distance of several hundred feet from the well.

A "tube" well, or "driven" well, will be little, if any, better whatever, unless the tube is sunk to a depth approaching one hundred feet, except in a few cases.

In addition to this we have already seen that such soils very often contain large amounts of organic matter, naturally present, and that this amount may be of itself so large as to produce malarial fever, by drinking the water. These considerations are of especial importance in regard to the well waters of southern and central New Jersey, and in regard to the possibilities of obtaining a really and permanently pure water supply, public or private, at the seaside resorts of that State, which must be considered by the sanitarian to be decidedly a doubtful matter, until careful chemical investigation can prove the contrary to be true.

It has lately been discovered in Massachusetts that some kinds of rock are no real hindrance to the direct percolation of cesspool sewage through them. In one case the well was sunk down into the solid rock for some distance, and the walls of the well were with the utmost care laid in mortar and coated with hydraulic cement from the surface of the ground down to the rock. Yet with all this care contamination took place from a cesspool on the opposite side of the house and fifty

feet distant from the well. The sewage was shown to have passed down through the rock at right angles to the dip or inclination of the rock, which was about 45°. The rock was sandstone, and percolation took place between the joints or fractures in the strata. On the removal of the cesspool to a distant part of the premises the water became decidedly better. The account of this remarkable case was published by Dr. Pinkham, of Lynn, in *Scribner's Monthly* for 1877.

From the brief study we have made of this subject in this lecture we may sum up the following conclusions to which we should carefully give practical attention.

On no account should we ever allow a cesspool, vault or surface privy within a radius from a well equal to twice its depth.

No drain pipe, whether of iron or terra cotta, should ever be allowed within this distance on account of the danger of leakage. The best laid drains have been frequently found to leak in the most unexpected places, and where especial care had been taken to prevent it.

In the case of houses on small lots of ground in a town wells ought never to be used at all for drinking. The Board of Health of such towns should have full legal power to close up all such wells, and remove the pumps, even if no positive disease has ever arisen from their use, or even if no complaint has been entered by a person residing in the immediate neighborhood. The Board of Health should also have power to prohibit any new wells being dug on premises of less than a certain fixed size.

Where a system of sewerage exists cesspools should be totally prohibited under penalty of law, unless such cesspools are built absolutely water tight, and kept so, and are thoroughly ventilated by tall pipes or chimney stacks, and the contents are frequently and regularly removed.

A certificate of compliance with these conditions given by regular official sanitary inspectors should be required at regular stated periods, say once a year, of every person having such cesspools on his premises.

No new cesspools should be allowed under penalty of law, unless by a certificate granted by a regular official sanitary inspector.

When a system of sewerage does not exist in a town the same law should be made to apply wherever the houses are not very scattered. In rural districts the law would be inapplicable.

All wells located near sewers or under street pavements, or exposed to contamination from street gutters, should be immediately closed and

the pumps removed. Such wells are extremely dangerous and a direct menace to the public health. In cases where a right of way to such a well is granted to several property holders by deed of title the Board of Health should have legal power to overcome resistance to its action so as to prevent all further use of the well, under penalty of law. A case of this kind has lately become known within the limits of Philadelphia, which I was requested to investigate.

In all cases of refusal of property holders to comply with such requisitions of the Board of Health, the latter should have power to proceed as in ordinary cases of public nuisances.

A modification of the law should be made so as to include within its prohibition all such wells as are likely, in the opinion of regularly constituted sanitary authority, to become polluted in the near future as well as those which are now actually in a polluted condition.

[In his concluding remarks the lecturer spoke of the minute living animals found in river water, and exhibited by means of the lantern several photographs of animal and vegetable life found in the water supplied to London in 1851 and 1854, which were years when cholera was violently epidemic in that city.]

These photographs are taken from plates in Dr. Hassal's work on adulteration of food. I wish to express, however, my strong dissent from the opinions of Dr. Hassel as to the injurious character of these animals and diatoms themselves. I believe that no clear and positive evidence whatever has ever been brought forward to prove with any degree of certainty these forms of life themselves to have been the cause of disease. They could not have caused cholera in London, for many of them, nearly all perhaps, are stated to be found in the Schuylkill river water at the present time, and yet Philadelphia was, at least in 1872, exceptionally free from cholera at a time when it was epidemic in other parts of the country. No disease has ever been proved attributable to these living forms in the Schuylkill river.

The chief point to be considered is, what may be associated with these animalculæ and upon which they may feed, or in some way be the indication of its presence. Some of them, undoubtedly, live only in comparatively good water, in proof of which statement, the reader is referred to the work of Dr. Macdonald on the microscopic analysis of water. Some of them require a polluted water, and one which contains sewage in not too great amount will often be crowded with some

forms, as was the case with some of the London water, which in 1851 and for some years after, was taken from the river at the London bridges, where contamination with sewage was very great.

These animalculæ, therefore, may be an indication of organic filth in the water, and this filth may be excreted from the intestines of diseased people. The animalculæ themselves are probably no more injurious to a human being than raw oysters. In all probability they can be digested with equal rapidity, and there is, as far as we know, no possible way for them to get into the blood in a living state.

[Photographs were also exhibited of the fresh-water algæ which were the cause of the disagreeable pig-pen odor in the Boston water a few years ago. These were from plates drawn by Prof. Farlow, of Harvard, for his paper in the Massachusetts State Board of Health Report for 1879.]

Electro-motive Force of Amalgams.—Hockin and Taylor find that potassium, sodium, cadmium, tin and copper become more strongly negative, iron and zinc more strongly positive by amalgamation, whether in acidulated water or in sulphate of zinc. Mercury retains hydrogen more strongly than other metals; its surface can be depolarized by a trace of sulphate of mercury or of bichromate of potash. In this case the electro-motive force of mercury, which contains a little zinc, varies from ·24 to 1·498; a very small quantity of positive metal dissolved in mercury can therefore greatly modify its place in the electric series.—*Les Mondes.* C.

Mutual Action of Magnetic Needles in Liquids.—Obalski has recorded a pretty experiment with two magnetic needles, suspended above a vessel of water by a delicate thread, and removed from one another by a distance slightly greater than the sum of their radii of mutual attraction, their opposite poles being near each other. A caoutchouc tube, filled with water, allows the level to be gradually raised or lowered without the slightest agitation. As soon as the needles are immersed they approach each other, on continuing to raise the level of the liquid the approach increases, and finally, when the submergence has reached a third or a fourth of the needles, the two needles rush together. A similar phenomenon occurs when the needles are suspended by their like poles. While in the air their mutual repulsion is hardly perceptible, but the free extremities gradually move asunder as they become submerged.—*Comptes Rendus.* C.

AN INQUIRY INTO THE LAWS OF THE BEAUTIFUL IN MUSIC.

By H. A. Clarke,
Professor of Music in the University of Pennsylvania.

Paper read before the Utopian Society, with additions, December, 1880.

The laws of the beautiful in music are very difficult of ascertainment, owing to the total absence of any objective standard with which the results of this art may be compared. We judge of the poet by the power with which he presents what human experience recognizes as truth, or by the keenness with which he analyzes passions with which we are all familiar. The sculptor has the form of man and of animals as a standard with which to compare his work. The painter has the endless variety of nature to guide him. Hence these arts are imitative—not, in the strictest sense of the word, creative. But in the art of music none of these helps are to be found. Outside of ourselves music is non-existent. Nature, with all her endless variety of sounds—beautiful as many of them are—has no music, gives us no hint of any standard with which to test the creations of the musician. The songs of birds, the murmur of streams and all the sounds of animate nature owe their beauty chiefly to circumstances and association, and are wanting in the first element of music.

We are then driven to the conclusion that music is a pure creation of man. Nature has taught him nothing. Other arts find their material and their motive ready and waiting for them. The beauty of nature would be the same had poet, sculptor and painter never lived; but the beautiful in music had to be slowly and laboriously evolved by man himself. He must first select from the great mass of sounds those that will form a scale—an operation that took some five thousand years. He must devise laws for the combination of these sounds. He must patiently spend centuries in devising instruments for the production of these sounds, and must learn by ceaseless effort to use these instruments. And even when all this is done the result may not be music, or may be bad music, which is the same thing. This brings us to the question. Why is *this* good music? Why is the other bad music? Are not both straitly conformed to the rules?

Yes. Cannot both be equally well performed? Yes. Then what is the intangible something which makes such a vast gulf between them? We cannot, and never will be, able to say. For want of a better explanation we call it genius; but this only removes the question a step further. As I said before, man has had to make his own standards in this art, and the inevitable consequence of having no independent standard is, that the ideal of good music has varied and always will vary while humanity exists. The most we should say of any composition is that the majority of those *best* qualified have consented to its superiority. In short, no definition of good music can be given until we can trace with unfailing precision the connection between sound and emotion, or sense and sensation.

It is comparatively easy to account for the emotions excited by the sister arts. They appeal to universal experience. As an illustration, the pleasure of looking at a well painted landscape is chiefly made up of memory. We all have memories, more or less vague, of beautiful scenes of wood, or seashore, or mountain; these memories are appealed to by the painters, and our gratification is in proportion to the truthfulness, as we call it, of the appeal. We thus have at hand a means of checking our impressions by this hardly conscious reference to well known standards.

But what experience or analysis or memory will account for the emotion excited by a Beethoven symphony? What is it when reduced to its elements but a heterogeneous mass of sounds, of various pitch, quality and intensity. All attempts at explanation have failed and must fail. One of the greatest of philosophers has tried to prove that the imitation of natural sounds is the origin of music—falling into the mistake so common to scientific men, of confounding *sound*, no matter how agreeable, with music; whereas, sounds bear the same relation to music that pigments do to painting.

But although we are unable to say what constitutes beauty in music, we are able to state with some confidence certain necessary conditions to which it must conform, or it could not be beautiful, still remembering that it may fulfill these conditions and yet resemble music only as an architectural drawing resembles a picture.

The first and the fundamental law of music is rhythm. Rhythm in sound means the same thing as symmetry in form. Symmetry, as defined by Ruskin, is the reproduction at equal spaces of the same figures and the same arrangement. Rhythm is the reproduction of an

accent at equal intervals of time. It is strange that the flight of time should be one of the essential conditions of this the most evanescent of the arts. We are not without proofs that rhythm is the true genesis of music. The music of all savages and of the ancient civilizations was largely composed of pulsatile instruments as the sistrum, crotalus, drum, cymbal and so on. We have here the first quality that distinguishes music from natural sounds; no sound in nature, not even the songs of birds, is rhythmical. Philosophers have tried to explain this inherent love of rhythm and symmetry in the hypothesis that space and time are so vast that the human mind shrinks from any attempt at their comprehension as wholes, and feels the need of some recurring points of rest, without which it is lost in their vastness.

I must digress here for a moment to give my reasons for believing that music originated in the love for rhythm, not in the attempt to imitate natural sounds. Mere noise, when rhythmic, is a great exciter of the passions, particularly of the savage's master passion—the love of fighting. Hence all nations, savage and civilized, have used and still use drums, cymbals, gongs, etc., as a necessary part of their war material. It is a common custom with savages when sitting round their camp fires or at their solemn "pow-wows" to recite the deeds of their warriors or ancestors, the recitation being accompanied by the beating of drums in regular rhythm. This recitation would soon accommodate itself to the drum beat and would develop into a rude chant. The voice would naturally rise when describing how the hero slew his foes and would fall when lamenting his death. The repetition of the same story, with the same inflections of the voice, would give rise to a rude melody. It would seem that the ancient Greek music arose in this way because it was lacking, as far as can be known, in *musical* rhythm, *i. e.*, the rhythm depended on the poetry, the musical sounds having no definite value. We have here the practice of recitation to musical sounds carried to its highest development. They, the Greeks, neglected the rhythmic accompaniment and bestowed all their attention on the reciting chant. It is to them we are indebted for all the forms of chant we now possess, viz., the Gregorian or Ambrosian and Anglican. It is strange that with their keen artistic sense they should have taken the wrong direction in this art and never made the discovery that rhythm in the *music*, not the *poetry*, was the true path to the highest development of the musical art.

But although cultivated music took this direction, the "Folk-music,"

i. e., dances and songs, were all of necessity conformed to rhythm, and it is to them that our modern music must trace its origin. The feeling for the combination of melody with rhythm gradually displaced the chant forms, and in the thirteenth or fourteenth century first claimed the attention of cultivated musicians, and has since gradually, but surely, displaced the older form which is now only retained in civilized countries in a modified form for religious purposes. In short, a close study of the history of music seems to indicate that it began with rhythmic noise produced by drums or even by striking two sticks together—to this was added recitation—this developed into the chant, consequently vocal music, as we know, was first developed. But, the universal practice of dancing also required some rhythmic accompaniment. This the drums, triangles, etc., would also supply, still united with voices, which would be compelled to measure their lines or sentences in such way as not to interfere with the rhythmic movement of the dancers; as instruments improved the use of voices for this purpose would gradually disappear, and from this has grown measured instrumental music; in proof of this all the compositions for instruments, with few exceptions until the close of the eighteenth century, were collections under the name of "Suites" of dances, such as gavottes, gigues, sarabandes, etc. So the savage had rhythm without music, the ancients music without rhythm—it was left for the moderns to combine the two and develop all the resources of the art.

The next law—one degree higher—is melody. This is dependent on the first law, and consists of sounds of different pitch adapted to some predetermined rhythm. Melody is one remove farther from natural sounds. It presupposes a definite arrangement of sounds called a scale, a thing that does not exist in nature, as every one knows who has tried to write down the songs of birds, all of which are constructed of intervals that do not exist in our scales.

The third and a still higher law, but still dependent on the two previous, is harmony, or the art of combining sounds. Melody and harmony are to each other as drawing is to painting. Drawing may exist without painting, but not painting without drawing—or, at least, it is very poor painting. So melody may exist without harmony, but harmony without melody makes very poor music, if it deserves the name at all.

Again, a skilfull drawing will, as painters say, suggest the color, and give an exact representation of the object; but the completed

painting, with its gradations of light and shadow, its blending and contrasting of tints, seems to bring nature herself before us. So a beautiful melody heard alone will give suggestions and hints of its capabilities of expression; but with the composer's harmony it brings before us his whole thought, with every shade of expression enhanced by the tints of the harmony. We are now far beyond nature, which has no hint or suggestion of musical harmony. It is man's own kingdom. He created it after centuries of work, and has possessed it for little more than two centuries. The fourth and highest law in music is form. As we advance, the mystery that surrounds the art deepens instead of clearing up. Who can say by what process of reason or instinct we have arrived at what we recognize as the highest form in music—the sonata? Why have we decided that the theme that is suitable for sonata treatment will not do for rondo treatment, and the reverse? Or, why is the sonata a higher, nobler form than the rondo? Form is an extension or development of rhythm. We have first the rhythm of the bar, then of the phrase, then of the theme, and lastly of the alternation and recurrence of the various themes. It might be compared to the revolution of satellites round their planets, of planets round their suns, and of suns round their unknown, unsearchable centre—*the ideal* of the composer.

I have now stated all that is definitely ascertainable concerning the laws of the being of this art. It seems very little; but when we remember that it is the unaided creation of man, we have a truer appreciation of the difficulties that he has had to overcome since he first attempted by rude drums and cymbals to divide time rhythmically, or by pipes and strings to make weak attempts at melody, or by barbarous successions of fourths and fifths essayed to combine sounds into harmony. From these rude beginnings has grown this most perfect of the arts. And it would seem in our day that its forms and means of expression have been all elaborated to their greatest possible perfection, and that no advance can be made until a *new* scale and a *new* harmony—of which we cannot even conceive or see any indications—be evolved.

Silver Plating.—In plating German silver H. Krupp, of Vienna, first deposits a galvanic coating of nickel, next a coating of copper and finally a coating of silver.—*Dingler's Journal.* C.

Photographs of Nebulæ.—Janssen, in congratulating Draper upon his successful photograph of the nebula in Orion, recommends that the greatest possible number of photographs should be taken, in different observatories where there are suitable instruments and skillful observers, in order to provide for a systematic study of nebular changes. He has made preparations accordingly at Mendon, and he proposes to construct, upon a large scale, a telescope similar to the one with a very short focus with which he obtained in 1871 a very luminous spectrum of the corona.—*Comptes Rendus.*

An Aged Teacher.—Michel-Eugene Chevreul, although he has entered upon his ninety-fifth year, still continues his lectures at the museum of Natural History in Paris. He was elected a member of the Institute in 1825 and he is invariably in his seat at the weekly sittings of the Academy. He was appointed Professor of Chemistry in 1830, and for fifty years he has continued his instructions without having ever been required to provide a substitute. The manuscript of his programme for 1880 is written in a bold and beautiful hand. His figure is tall and imposing, his appearance still young and fresh looking, his manners genial, calm, gentle, and he always welcomes his visitors with a smile.—*Les Mondes.* C.

Nutricine.—E. Moride has prepared a new elementary substance which he calls nutricine. He combines raw flesh with other nitrogenous food which absorbs the juices of the flesh and, perhaps, forms with them some organic combinations which are, as yet, undetermined. He dries the whole in the air or in a stove moderately heated, then pulverizes and sifts it. The powder is of a fine gray or yellowish color and of an agreeable taste. It may be solidified by gum water, albumen or grease, so as to form tablets, cylinders and cubes of various weight, which can be divided, as needed, for making soups, sauces or biscuits. The nutricine contains all the elements of the flesh in their natural condition; even the blood preserves all its properties of solubility, coloration and coagulation under the influence of heat. It is more nitrogenous and more nourishing, for equal weights, than meat itself, because all the worthless portions of the meat are rejected and the fluids are replaced by farinaceous substances, which contain some additional amount of nitrogen. The same system, when applied to the blood or meat of horses and the refuse of abattoirs, gives a useful food for dogs, hogs, chickens and ducks.—*Comptes Rendus.*

The Atlantic Cable and Hughes Telegraph.—By using the Tomasi relay the Hughes telegraph has been able to print messages which were transmitted through resistances far greater than those of the Atlantic cable, and Abbé Moigno ventures the prediction that the experiments will soon be successfully repeated with the cable itself.—*Les Mondes.* C.

Paste for Paper.—To ten parts by weight of gum arabic add three parts of sugar in order to prevent the gum from cracking; then add water until the desired consistency is obtained. If a very strong paste is required add a quantity of flour equal in weight to the gum, without boiling the mixture. The paste improves in strength when it begins to ferment.—*Chron. Industr.* C.

Burnt Steel.—Mere heat does not harm steel or iron; they may be heated and cooled an unlimited number of times, provided they are not allowed to come in contact with the air so as to absorb oxygen. In heating a piece of steel the amount of blast has much more to do with the burning than the heat. If the extra oxygen is taken out of the burnt steel it can be made to work just as well as it did before. The proof that heat does not harm steel is found in the fact that if a piece of steel is put in a closed box, and luted up so as to keep out the air, it can be heated and cooled an unlimited number of times without injury.—*L'Ingen. Univ.* C.

Light and Electricity.—In 1873 W. C. Röntgen was led by observing that a glass plate which had been fractured by the electric spark became doubly refracting, to inquire whether a similar influence might be exerted by electricity without fracture. Kerr, Gordon and Mackenzie subsequently published a series of experiments upon the subject, none of which seemed very conclusive until Kerr's communications appeared in the *Philosophical Magazine* for 1879. Röntgen was then induced to experiment with various substances, and he found that transmitted light undergoes changes through electric influences which are precisely similar to those of ordinary double refraction. The intensity varies in the electrical field with the electrical force, and it increases with the difference of potential between the electrodes. By these experiments he has succeeded in thoroughly confirming the classification of fluids as positive and negative.—*Ann. der Phys. und Chem.* C.

American Sewing Machines. — The value of the sewing machines exported last year was as follows: Germany, $539,000; Great Britain, $481,000; Mexico, $153,000; Australia, $110,000; Colombia, $83,000; Cuba, $66,000; France, $41,000; South America, $84,000; Central America, $12,000, and other countries $82,000, making a tatal of $1,661,000.—*Fortschr. der Zeit.* C.

Photographing the Chromosphere.—Janssen has been induced, by his late novel experiments, to undertake photographs of the chromosphere. He allows the solar luminous action to continue so long that the solar image becomes positive to the very circumference, without going beyond it. The chromosphere is then shown in the form of a dark ring, with the thickness of 8″ or 10″. He has compared positive and negative solar photographs, which were obtained on the same day and with the same instrument; the measurement of the diameters shows that the dark ring in question is wholly outside of the solar disk. *Comptes Rendus.* C.

Nervous Velocity in the Lobster.—Frédéricq and Vaudevelse have been experimenting upon the velocity of transmission of the motive excitement in the nerves of the claw of the lobster. They used the graphic method, which was employed by Helmholtz in his researches upon the propagation of the nervous motor influences in the frog. In the winter experiments, at Ghent, with a temperature of 10° to 12°C. (50° to 53·6°F.) they found a velocity of about 20 feet per second. In the summer experiments, at Roscoff, with a temperature of from 18° to 20°C. (62·4° to 68°F.) they found velocities of from 30 to 40 feet per second.—*Comptes Rendus.* C.

Thermal Theory of the Galvanic Current.—J. L. Hoorweg lays down the following laws: *a.* When two conductors come into contact a warm current produces a development of electricity, hence arises a constant electrical difference between the two substances. *b.* If the sum of the potential differences in a closed circuit varies from zero a continuous electrical current arises in the circuit. *c.* This current exists at the expense of the heat in one of the points of contact, and it develops heat at the other point. *d.* All voltaic currents are thermal currents. *e.* The chemical action in the battery and the decomposition are consequences of the galvanic current.—*Ann. der Phys. und Chem.* C.

Advantages of Steel.—Dr. Siemens, whose thorough competence is universally known, claims that in every case when strength and magnitude are both required the use of steel is without a rival. He asserts that even for an ordinary house steel gives more security than wood, is six to eight times as strong, and costs less. He thinks that before many years elapse we shall see steel introduced into buildings of all kinds, and that it will gradually supplant iron, in the same way that iron already tends to take the place of wood.—*L'Echo Industr.* C.

Relations between Chemical Mass and Heat of Combination.—Berthelot finds that the elements which belong to any group, when they unite with any given simple body in order to form comparable compounds, set free quantities of heat which vary inversely with the chemical mass; the stability of the compound decreases in the same ratio. The decrease sometimes extends even to the change of volume which is produced by the combination of solid elements, when they form a solid compound. We are thus enabled to investigate the mechanical significance of the various relations.—*Comptes Rendus.* C.

Book Notices.

A Course on the Stresses in Bridge and Roof Trusses, Arched Ribs and Suspension Bridges. Prepared for the Department of Civil Engineering at the Rensselaer Polytechnic Institute. By William H. Burr, C.E. 8vo. New York: John Wiley & Sons, 1880.

Any one who has been through that Institute can realize the advantage given to the student by a work of this kind, a text-book prepared by his own instructor, adapted by him to the course which he teaches, arranged according to the methods and nomenclature of that instructor and considering just those subjects which he feels to be most important for the present wants of his pupil. This was particularly the case in the writer's day, when the lecture system was so largely used, and a work of this kind, especially at a time when few, if any, books on the higher branches of engineering were published or accessible, would have been, indeed, a great boon. How far this want now obtains, and

what methods are used at the Institute, the writer is unable to say, but he has no doubt that even with the host of reliable text-books within reach of the student, the present work will still supply a deficiency, particularly at that school, and also outside of it.

The writer is well aware that many practical details, important and essential to the engineer, are not treated of in works of this kind, and it would be better if they could be. Unfortunately, however, the professors of our institutions seldom have the practical knowledge necessary to so treat them. The compensations paid are not usually sufficient to enable a man highly skilled in practical attainments by many years of service to accept such a position, as he can do better in the active practice of his profession outside. On the other hand, the practical man has seldom the time, or that inclination to literary pursuits, requisite to produce a good book. His practical experience, too, is part of his "stock in trade," and he does not always care to part with it. Our engineering societies are helping very much in this matter, encouraging the preparation and reading of papers, and must be mainly relied upon to further this branch of the subject.

All that the student can do in his four years' course at college, and all that is expected, is that he shall advance so far in his theoretical studies, with such practical information as it is possible to give him, to put him in a position to continue his work of gaining knowledge by himself after his college days are over, and to enable him to take a low position in actual service, where he can gain the practical part of his profession, working it up in connection with the theoretical, applying the latter wherever he can, and gaining for himself a place in the world. It would be impossible in four years to gather in all the instruction necessary to turn out a full-fledged practical engineer. It is a great mistake to think so, and although our young graduate comes out sometimes with this idea, the sooner his mind is disabused of it the better for himself and for others. The best student who ever graduated, when he leaves college is nearly at the foot of the ladder.

We are led to these remarks by reading a criticism on this work from another paper, and we want to say that we believe this book has been prepared by the author for *students*, particularly those of the Rensselaer Polytechnic Institute, not for the man who wishes to learn the *practical* part of his profession.

The theory as a usual thing *must* be taken up at the student time of life, when the brain is clear and active, unoppressed with cares of a

professional business. Let the student get what practical part he can; do not deny it to him, but do not make a sacrifice of theory for it.

J. M. W.

THEORY OF SOLID AND BRACED ELASTIC ARCHES; applied to Arched Bridges and Roofs in Iron, Wood, Concrete or other Material. Graphical Analysis. By Wm. Cain, C.E. 18mo. New York: D. Van Nostrand, 1879.

Another one of those useful little books comprising the Van Nostrand science series is now before us.

This is the third volume which Mr. Cain has issued on the subject of arches. The others, particularly that on voussoir arches, have been employed by the writer in practical work for some time, and he can testify to their usefulness. The principles involved in the discussions contained in the present volume are believed to be entirely correct, and the results are in such a form as to be practically available by the engineer in any operations concerning arches which may occur in his business operations, matters that until within the last few years have been difficult of solution without much labor, and even then, perhaps, involving more or less uncertainty.

The writer well remembers the pleasure with which he perused Mr. Baker's paper on arches some years ago, followed afterwards by Bell, in his communication to the Institution of Civil Engineers, whose method was a great advance on anything hitherto accessible. He feels sure that engineers will welcome Mr. Cain's contribution, as adding considerably to our knowledge on this interesting subject. J. M. W.

DWELLING HOUSES: THEIR SANITARY CONSTRUCTION AND ARRANGEMENTS. By Prof. W. H. Cornfield, M.A., M.D. No. 50 of Van Nostrand's Science Series. New York: D. Van Nostrand. 1880.

The work before us consists in the reprint from *Van Nostrand's Magazine* of a series of lectures upon a subject which ranks among the most practical of those which press themselves upon our consideration; already dignified as a science, although a growth of but thirty or forty years at the most, it claims among its votaries men of talent and learning, often attracted by the opportunities it offers for exercise of their capabilities for usefulness in a sphere of such unquestioned practical importance. The prevalence of serious diseases which scientific dis-

covery has associated with filth in its various forms, has tended to enlist the interest of all classes, and in direct proportion to their enlightenment, even the sordid and mercenary are compelled to recognize its importance from a money standpoint. And while it may be, as is too often the case, that the hobby is saddled with more than its legitimate burthen, nevertheless the agitation of the matter will be the surest method of arriving at the truth, which may be said in the present case to often literally lie "at the bottom of a well." The following paragragh is so suggestive of the practical nature of our subject it requires no comment:

"It has been clearly shown that the dampness of the soil under the houses is one of the great factors in the production of consumption. Dr. George Buchanan (see ninth report of the Medical Office of the Privy Council) demonstrated that in every instance where the level of the subsoil water in a town has been lowered, that is to say, where the distances between the basements of the houses and the level of the water in the soil had been made greater, the death rate from consumption had decreased, in one instance to the extent of not less than fifty per cent."

Attention is also directed to the evil that is known as "made ground" in the neighborhood of towns, consisting of rubbish of various kinds used to raise the surface to the proper grade; we do not think, however, that our author is emphatic enough in his protest against what we regard as an unjustifiable disregard of the simplest sanitary knowledge, for a large element in this rubbish consists of tinman's scraps, which with ashes, etc., create a porous and unstable foundation, liable to settle for a long period after being built upon, and in an irregular manner, thus disturbing the foundations, while providing facilities for the formation of foul emanations.

Attention is also directed to the all-important fact, that water which does not indicate impurity of any kind to the senses may yet contain injurious substances in solution, which can only be discovered by chemical analysis, although they may often be suspected from its history. While the work is pregnant with important suggestions, the principal fault lies in the attempt to illustrate without cuts which, in a popular publication, is unsatisfactory, as it presumes an ability of discernment which the average reader does not possess; there is, however, much which we commend to the perusal of all who desire to take nformation in homœopathic doses and agreeable forms. W. B. C.

Franklin Institute.

HALL OF THE INSTITUTE, December 15th, 1880.

The stated meeting was called to order at 8 o'clock P.M., the President, Mr. William P. Tatham, in the chair.

There were present 160 members and 35 visitors.

The minutes of the last meeting were read and approved.

The President announced that nominations for officers to serve the ensuing year were, in accordance with Article XIV, Section 7, of the By-Laws, the privileged business of the meeting, and after the reading of the names of those whose terms had expired he asked for nominations.

Mr. Cartwright nominated the retiring members of the Board.

The following members were placed in nomination:

For President, William P. Tatham.

Vice-President, Charles Bullock.

Secretary, Dr. Isaac Norris.

Treasurer, Frederick Fraley.

Managers, Washington Jones, Pliny E. Chase, Joseph M. Wilson, Theodore D. Rand, Coleman Sellers, Charles S. Heller, Frederick Graff, W. L. Du Bois, H. P. M. Birkinbine, George V. Cresson, Henry G. Morris, Robert Briggs, A. E. Outerbridge, Jr., Henry Seybert, Dr. Charles M. Cresson.

For Auditors, W. B. Cooper and Louis S. Ware.

Representative in Pennsylvania Museum and School of Industrial Art. No nomination made.

The Actuary presented the minutes of the Board of Managers, and announced that 19 persons were elected members of the Institute at their last meeting.

The Secretary reported the following donations to the Library:

Publication Industrielle des Machines, Outils et Appareils les plus perfectionnés, etc. Par Armengaud ainé. Vols. 1 to 10 of text and Vols. 1 to 10 of plates. From Fred'k Graff, Philadelphia.

Steam Boilers, their Design, Construction and Management. By W. H. Shock. From B. H. Bartol, Philadelphia.

Proseingamento del Lago Fucino Eseguito dal principe. D. A. Torlonia. Firenze, 1871. From Fred'k Graff.

Reports from the Consuls of the United States on the Commerce, Manufactures, etc., of their Circular Districts. No. 1. Oct., 1880. From the State Department, Washington.

Les Tarifs des Chemins de Fer et l'autorité de l'Etat. Par M. Léon Ancoq. From the Author, Paris.

Annual Report of the Surgeon General, U. S. A., for 1880. From the Surgeon General.

United States Coast and Geodetic Survey. Appendix 13 to Report for 1877. From the Survey Office, Washington.

American Ephemeris and Nautical Almanac for 1883. From the Bureau of Navigation, Washington.

Report of the Commissioner of Fish and Fisheries for 1878. From the Commissioner, Washington.

Annual Report of the Secretary of War for 1880. From the Secretary, Washington.

The Steam Engine Familiarly Explained and Illustrated. By D. Lardner. From W. P. Tatham, Philadelphia.

Journal of the Royal Geographical Society. Vol. 49. 1879. From the Society, London.

Annual Reports of the Adjutant General of Pennsylvania for 1864 and 1874. From the Adjutant General, Harrisburg.

The Northwestern Miller. January to August, 1880. From the Publishers, Minneapolis.

Second Geological Survey of Pennsylvania. Reports C^3, C^6 Maps; G^2, G^3; I^3; O^2; R; T; V^2.
From the Survey Office, Harrisburg.

Mr. W. Barnet Le Van read the paper announced for the evening, entitled "Ninety Miles in Sixty Minutes, or How to Accomplish the Distance between New York and Philadelphia in One Hour."

The paper was a continuation of one read by him, some time ago, on High Railway Speeds (see JOURNAL for July, 1880), and undertook to show the difficulties in the way of running trains at this high speed at present, and how they could be overcome. The subject was treated from a technical point of view, but some of the facts mentioned were of general interest. Thus, the distance in an air line between New York and Philadelphia was stated to be a fraction less than 81 miles (80·9), over a comparatively level country. The existing roads are far from being straight. On the Pennsylvania line, in the 88·4 miles between Philadelphia and Jersey City, there are 84 curves (fifteen in the fifteen miles between Germantown Junction and Schenck's Station). The greatest length of straight track between this

city and Trenton does not exceed three miles, and the greatest in the entire road does not exceed ten miles. The Pennsylvania Railroad is not responsible for this condition of the road, but has, in fact, done much to straighten the line, and, notwithstanding these drawbacks, runs trains on the road at the rate of 50 miles per hour. On the Bound Brook route there are forty-three curves, one on the bridge crossing the Delaware river, which has a radius of 2865 feet, is 1837 feet long and ascends 19 feet to the mile. The greatest stretch of straight track is from Skillman's east—14 miles. To compensate for the centrifugal force tending to throw the cars from the track when running at high speeds on curves the outer rail has to be raised. On a curve of three degrees radius the super-elevation required on a gauge of fifty-six inches, while less than five inches at fifty miles an hour, would have to be *sixteen* inches at ninety miles per hour. On the Pennsylvania road the super-elevation is one inch for each degree of curvature up to five inches, which is the limit. The speed must be reduced beyond that to correspond with the curve. This is one of the limitations put upon high speeds on existing roadways. Mr. Le Van considered others at great length, and summed up by saying that, after a careful study of the subject, he was satisfied that a paying road could be built to run in a straight line between New York and Philadelphia, reducing the distance about ten miles, and enabling trains to be run through in sixty minutes. One of the means of effecting this purpose would be a reduction of the dead-weight in the trains. The fast trains now running between this city and New York have generally four cars with engine and tender, weighing 232,000 pounds, or 116 tons dead load, and are 264 feet long. For from four to eight tons of passengers carried, trains are made up weighing from 110 to 150 tons.

Mr. Le Van thought it would pay to build a line so perfect in all its details as to exclude rival lines, and attract to itself all the through business. The line he pictured crossed no roads at grade, and had only two curves of 10,000 feet radius each.

Mr. Nystrom said that there were two distinct problems in Mr. Le Van's project—one geometrical, the other dynamical. The geometrical problem was as to whether a straight line was the shortest between two points, an axiom that does not seem to have been recognized by railroad engineers. He did not think the dynamical problem difficult to solve. There would be no difficulty in going to New York in even less time than Mr. Le Van proposed, so far as driving the engine was

concerned; the chief difficulty is in getting roadway strong enough and stable enough to stand the pressure.

A curiously constructed high speed rotary engine was shown, the invention of Mr. Tegnander, of Gothenburg, Sweden. It is a double-acting engine, the cylinder having four chambers and pistons, and when the steam enters the chamber it acts on the bottom and top of each alternate piston. The piston rods are connected through ball bearing with a circular plate keyed on the engine shaft, and when the latter is made to revolve by the steam pressure its rotary motion is transmitted to the cylinder and pistons, so that every part of the engine is kept revolving except the slide and steam chest. The inventor claims that the engine is balanced with great nicety, so that the weight of the working parts is concentrated on the central line of the frame, and, consequently, there is very little vibration. The engine is comparatively small, easily managed, and the inventor claims that it is economical, and will give high speed with a minimum of wear and tear.

In answer to questions as to power of the engine, cost, etc., Mr. Lofquist, who exhibited it, said that the engine had about 8¼ effective horse-power, and when tested here was running at the rate of 800 revolutions per minute, with 50 pounds of steam pressure, driving a dynamo-electric machine, and the packing had not been touched since the engine had been tried in Sweden. For every 5 pounds pressure per square inch, the engine working with one-third expansion, the increase of power was 0·9 horse-power. With 100 pounds pressure the effective horse-power was 15, when tested in Sweden. The price at which such engines can be sold has not been determined. This one, made in Sweden and constructed by itself, cost about $200.

Mr. Orr inquired whether there had been any test of its durability. The reply was that there had been no prolonged test. This engine had been in use for about eight months, and was perfectly steam tight.

Mr. Robert Briggs said that his anticipations about this engine had been more than realized. It was one of the prettiest specimens of this class of engines that he had ever seen. It was not absolutely new, but presented many features that were improvements upon older engines. It is economical in bed plate, its moving parts are arranged so that it runs quite independent of any fly wheel, and it is therefore very well suited for use in small yachts. The first disk engine was made for this purpose, but could not be kept steam tight,

although in the hands of some of the leading engineers of England. This engine of eight horse-power represents one that, of another type, would weigh six or eight times as much. There are three or four movements of the same class, and Mr. Briggs described some of them.

Mr. Jones inquired whether Mr. Briggs remembered a Boston engine, with four cylinders, designed to be used as a fire-engine, saying that it appeared to him to be very similar to this.

Mr. Briggs said he could not recall that particular engine, but had seen several that were similar in form and movement.

Mr. Tatham said that at least thirty-five years ago an inventor came to Philadelphia from Richmond, Va., with plans of an engine substantially the same as this, and having the cylinder set at an angle to the engine shaft, like this.

Mr. Eldridge inquired whether the movement was not just the reverse of a blower shown at the Institute some years ago. In regard to the engine described by Mr. Briggs, and of which he had made a drawing, Mr. Eldridge said that he had seen one like it at the Paris Exposition two years ago.

Mr. Briggs could not recall to memory the blower mentioned by Mr. Eldridge, but, continuing his remarks, said that the disk engine in England had proved a failure. It differed, however, in its details from this.

Prof. Marks said that this and the engine described by Mr. Briggs were of a very old type, that has been re-invented about every five years since the beginning of the century. A full description of many of them may be found under the head of Chamber Crank Trains, in Reuleaux's *Kinematics of Machinery*, translated by A. B. W. Kennedy.

In answer to further inquiries, it was stated that a 30 horse-power engine of this type had been built as well as the one exhibited, and several of smaller horse-power. A recent number of the *Teknisk Tidskrift* states that considerable interest is being taken in the invention by the Society of Civil Engineers of Stockholm.

The Secretary's report included an account of Daniel's Safety Lock, where, by a simple adjustment, an increased security is obtained without additional cost in its manufacture, and after closing the door the mere operation of latching with the knob simultaneously bolts the lock, and throws a guard of chilled iron over the keyhole, preventing